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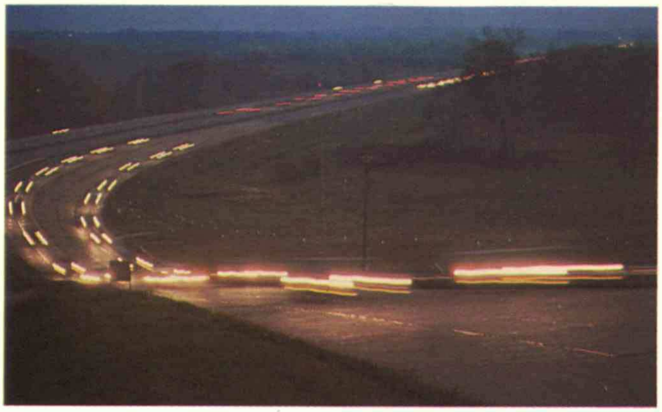
Technology Review

Edited at the Massachusetts Institute of Technology



The great sulfate experiment.

Large-scale experimental measurements by the Research Laboratories at General Motors have helped answer an important question in atmospheric science.

Predictions by some scientists had suggested that sulfate emissions from catalyst-equipped cars might reach dangerous levels by 1985. An unlikely occurrence—only under rare atmospheric conditions and if most cars have catalytic converters—but still a possibility, they said.

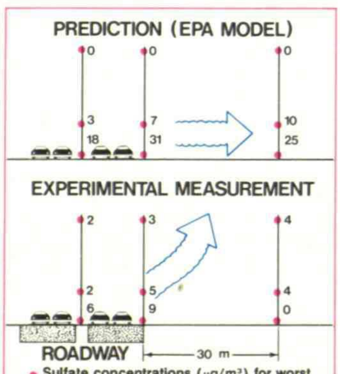
To get hard data, the Research Labs set up "The Great Sulfate Experiment." It was a public test—with the Environmental Protection Agency and other government and university researchers joining in.

Scientific evidence was gathered at the GM Proving Ground by simulating 1985 traffic. During 17 days, a test fleet of 352 catalyst-equipped cars rolled past our six testing towers, creating rush-hour traffic densities of 5,462 vehicles per hour.

During this time, sampling for sulfates and meteorological data took place at 20 points above and at ground level.

The finding: Roadway sulfate emissions are sent aloft by the turbulence and heat generated by vehicles.

It was a key discovery. Atmospheric scientists are now scrapping some old models of dispersion from roadways and drafting new ones based upon this unique data.



• Sulfate concentrations (μg/m³) for worst atmospheric conditions.

What's more, today's catalytic converter system—the best solution we now know for changing some other exhaust pollutants into harmless gases—is still free to do this important job.

If you would like more information on the experiment and its findings, we welcome your inquiry.

General Motors Research Laboratories
Warren, Michigan 48090

Edited at the
Massachusetts Institute of Technology

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Articles

Departments

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The First Line

From Suva to Athens in Six Months

There are no laboratories and textbooks, no reliable statistics. To study low-technology transportation, Alan Meier (*see "Becaks, Bemos, Lambros, and Productive Pandemonium" starting on page 56*) took to the streets of Southeast Asia.

He soon learned that government sources were not much help. Data on registrations are sparse; licensing is occasional; and statistics and reality turn out to differ by an order of magnitude. So most of Mr. Meier's research was conducted by behaving like a curious tourist: identifying vehicle types and then riding them, studying their networks and their technology, and talking to the people who used them, drove them, owned them, and repaired them. His nosy questions — especially those about economics — were politely, even enthusiastically, answered; most respondents seemed to assume he wanted to buy. Within three weeks of arriving in a city, Mr. Meier says, he often knew more about its transport network than most natives.

Newspapers helped especially because they recorded current problems and frictions in human terms. Mr. Meier soon learned to look for letters, cartoons, and editorials as well as news stories, and he sought out back issues in English-language libraries wherever he went.

It was hard work, from Suva to Athens in six months. But rewarding, says Mr. Meier — for himself and, thanks to sharp eyes and facile pen, for *Technology Review* readers. —*J.M.*

Letters

Intimations of Immortality

The June issue of *Technology Review* was particularly fascinating. The article by Frank Drake (*"On Hands and Knees in Search of Elysium," pp. 22-29*) deserves an added comment.

Dr. Drake didn't touch on the one problem I see — synchronicity. Consider the time scale, even in rough orders of magnitude. Say the earth (or universe) has an age of around 10^{10} years. Life on earth appeared in the Proterozoic era, 10^9 years ago. Man appeared in the last 0.1 per cent of this "age of life" — 10^6 years ago. Archaeological history digs into only 1 per cent of this human period — 10^4 years. Scientific investigation has a span of 10^3 years, while electronic communication has been in existence only 10^2 years. Of this, space communication is only within the last 10^1 years.

Even if intelligent beings were time-coincident with us to within $\pm$ 1 per cent, we could still be off 100 million years! This would give our search either a very long wait, or we'll be playing "whatever happened to. . . ."

John D. Fogarty
Columbia, Md.

Having visited the installation at Arecibo, which is fascinating both scientifically and aesthetically, I was happy to see it featured in the June issue of the *Review*. Despite its fixed position, Arecibo has been the site of magnificent work in receiving the signals of radio stars, in tracking satellites, and in exploring planets by radar. However, I fear that the search for communications from "other worlds" is doomed to frustration, and not less so if it succeeds than if it fails.

Three dimensions of the space-time continuum are commutative: you can go east and west, north and south, there and back. But the fourth dimension, time, is inexorably one-way. And the overwhelming percentage of objects in the universe are so distant that when we do receive a message from somewhere out there, responses may take centuries or millenia to travel. So on that hoped-for day when a signal arrives from an intelligent being, it will probably amount to hearing a rap on the door, and calling out, "Who's there?"

Then silence. Maybe our remote descendants will hear the answer.

Arthur Morgan
New York, N.Y.

Dr. Drake replies:

Mr. Morgan is entirely correct that the detection of another civilization may set a record in frustration. We think it is 1,000 light years to the nearest civilizations; thus the simplest dialogue takes a minimum of 2,000 years, which to anyone is greatly discouraging.

Those of us involved in the search for extraterrestrial intelligence see two pathways around the problem. First, *they* are aware of the problem, and can solve it by sending us, before we ask, the information we want to know, or should know even if we are not smart enough yet to realize it. Some astronomers have even concluded that transmitting civilizations will normally send two signals, one a strong, narrow-band signal designed to attract attention, but to say nothing other than the frequency at which to listen to the interesting information. This second information channel could be broad-band, with a high information rate, and would demand the application of expensive and sophisticated equipment, such as the radio telescope at Arecibo (Cyclops). But we should then be motivated to invest the required resources. It doesn't take many minutes to send the entire *Encyclopedia Britannica* on such a radio link.

The alternative is to intercept the signals of the other civilization, such as TV, and deduce the information (and misinformation, perhaps) one would like to know. This again calls for much larger instruments than are common today, instruments as large as Cyclops.

The quarantine imposed by vast interstellar distances is not just one of distance, but also of time. Most important, even if we discovered a civilization tomorrow, we would still need Cyclops.

What Is This Thing Called Nessie?

I find it hilarious that a pair of elephant seals appear to have caused all that scientific to-do (*"Search for the Loch Ness Monster," March/April, 1976, pp. 25-40*).

These curious and intelligent mammals were probably looking the scientists over in their boat when the scientists had a strong feeling of another presence. Elephant seals have much better night vision than man. They also use echolocation, so that they would have little difficulty with low water visibility. Their special skeletal structure allows them to stretch their necks rather surprisingly. Camera distortion made this look much longer. Back scatter seems to have exaggerated their body surface irregularities.

Apparently they seldom get much more than their nostrils and eyes above the water except when they come ashore to mate.

George D. Ray
Libertyville, Ill.

A medium-sized giant squid seems a reasonable candidate for the Loch Ness monster, but conclusive identification must await an actual sample, either of a complete individual or a portion. Since harvesting with a net is not feasible due to the underwater topography, if the animal is indeed a squid, it could be attracted by the strobe and an effort made to secure a piece of tentacle, arm, or mantle. Harpoons or explosives which might be effective in capturing a plesiosaur would be of little assistance with a squid. In any case, better photographs may resolve the issue. Some use might also be made of sensitive sonar which might be able to detect the difference between the "hard" echo of plesiosaur flesh and the "soft" damped echo of squid mantle.

We look forward to a definitive description of the creature and are not distressed that it has taken so long. After all, giant squids themselves were not scientifically authenticated until 1873.

Bonnie Dalzell
Jan Galkowski
Bruce Schatz
Yorktown Heights, N.Y.

The long neck, beak, size, aquatic habitat, flippers, and fish-eating characteristic of the turtle make it a likely candidate for the Loch Ness monster.

Continued on p. 17

The Hunting of the Quark

National Report
by
David F. Salisbury

Using the controlled violence of high-energy accelerators and the powerful logic of modern mathematics, scientists may have opened the lid of Nature's smallest Chinese box to discover at last the "indivisible particles" from which all matter is formed.

The Holy Grail of modern physics has been the discovery of particles without internal structure. Once all these particles have been found, their properties catalogued, and the rules of their interactions elucidated, the simple patterns which underlie the almost unimaginable variety of the universe should snap into focus.

Now this quest may be nearing its end. Recent discoveries in particle physics favor a theory which postulates the existence of unlikely particles called quarks and endows them with properties whimsically labeled flavor, charm, and color. But there is a good chance they will be impossible to detect directly.

Particle Grace

Four primitive particles have already been discovered, called leptons, from the Greek word "leptos," meaning small. The best known of these is the electron. Other members are the muon and two types of neutrino. These particles behave like points: they are very small, and have never been known to break down into other particles.

Protons and neutrons, however, are not at all like leptons. When slammed together at nearly speed-of-light velocities in the evacuated toruses of particle accelerators, the constituents of their nuclei shatter into hundreds of different particles. These particles have a measurable size, about 10^{-13} cm, and appear to have an internal structure. Scientists have dubbed them hadrons because they are thick and heavy.

Besides their apparent complexity, hadrons have another characteristic that distinguishes them from leptons. They are subject to the "strong force" which is 100 times stronger than electromagnetism and provides the glue that cements the nucleus together. Without the strong force there would be no chemistry.

In 1962, Murray Gell-Mann of California Institute of Technology and Yuval Ne'eman of Tel Aviv University independently discovered that hadrons, the superabundant prodigy of high-energy physics, have an underlying order. Dr. Gell-Mann and George Zweig, also of Cal Tech, went on to explain that these unexpected regularities could be understood if all hadrons were composed of three basic particles and their antiparticles. (An antiparticle is the mirror image of an ordinary particle. It has the same mass but opposite characteristics, such as electric charge.) Dr. Gell-Mann called these "quarks" from a line in *Finnegan's Wake*: "Three quarks for Muster Mark!"

"Quarks are at once the most rewarding and the most mystifying creation of modern particle physics," says Harvard University theoretician Sheldon Lee Glashow.

To explain events in the subatomic realm, physicists have adopted a convention called the quantum number. They have found that the actions of quarks can best be explained by assuming that certain properties vary only by discrete amounts, not continuously. These amounts are called quanta.

Originally, quarks embodied eight different quantized properties. Some — electric charge and spin, for example — are readily understandable. Others, such as strangeness and baryon number, are less easily grasped, and explain why quarks combine into some particles and not into others.

For instance, hadrons break down into families: baryons and mesons. It was discovered that the baryons could only be created and destroyed as baryon-antibaryon pairs. So scientists gave baryons a "baryon number" of +1, antibaryons −1, and mesons 0. Then they made the rule that in any interaction, the sum of the baryon numbers cannot change. Following this arbitrary rule keeps a meson from becoming a baryon without forming an antibaryon partner.

Baryons are thought to be made from three quarks, antibaryons from three antiquarks, and mesons from a quark-antiquark pair. Therefore quarks are assigned a baryon number of 1/3 and antiquarks −1/3. Thus the quark model remains consistent with baryon conservation.

In 1964, Dr. Glashow proposed a fourth type of quark having another quantized property which he called charm. His theory explains why certain interactions, not inhibited by the three-quark model, are extremely rare. With two pairs of quarks, a second reaction path is available which almost cancels out the reaction predicted by the three-quark model.

The fourth quark is assigned a charm of +1, its antiquark a charm of −1. All the other quarks and antiquarks are believed to lack this peculiar form of particle grace.

Dr. Glashow's theory predicted that particles containing charmed quarks remained to be discovered. To account for the fact that they had not yet been observed, Dr. Glashow made his charmers the most massive of the four quarks.

The Color of the Quark

The theory remained untested until November, 1974, when news came from Brookhaven National Laboratory and Stanford University that a new particle — the J-particle — had been discovered. It has a lifetime 1,000 times longer than is typical for hadrons of its mass.

Since then, theoreticians have become increasingly convinced that the particle — and its nine relatives subsequently discovered — are best described as combinations of charmed and anticharmed quarks. Only last summer, a candidate for a "nakedly charmed" particle, composed of a charmed quark and an uncharmed antiquark, was found.

This October, Samuel C. C. Ting of M.I.T. and Burton Richter of Stanford, leaders of the two teams that independently identified the J-particle, were jointly awarded the Nobel physics prize for their discovery.

Yet there is more to the world of the quark than charm. An even more abstract theory, proposed independently by Yoichiro Nambu of the University of Chicago and A. Tavkhelidze, a Soviet scientist, describes a quark's "color." Color

reconciles quark theory with a basic tenet of modern quantum physics: the special relationship between a particle's spin and its interaction with its twin. If their quantized spin is integral — 0,1,2,. . . — an unlimited number of particles can come together in one state. But if they have half-integer spins — 1/2, 3/2, 5/2,. . . — then there is room for only two particles spinning in opposite directions in each energy state.

Electrons have half-integer spins and obey the second rule. The result is the regularly varying electrical structure of the elements which gives rise to the periodic table.

Quarks, however, seem to violate this rule. They, too, must have half-integer spins for the angular momentum of the various hadrons to be predicted. But quark rules call for three identical quarks to combine to form three baryons. If the three quarks were different, then this apparent conflict would vanish. Thus quarks may have different "colors."

But it is color of a strange sort. As Dr. Nambu has worked it out, quark color is normally invisible. Quarks come in the three primary hues: red, green, and blue. Antiquarks are painted in complementary fashion: cyan, magenta, and yellow.

Hadrons, made up of three quarks, combine red, blue, and green in a whirling carousel of color. As with a spinning color wheel, they appear white. And mesons which combine a primary color and its complement would also appear colorless.

Color has come to assume an increasingly important role in quarkdom, since it may be intimately related to the force that binds quarks together. Color may be in some way analogous to electric charge. Quarks may change color by exchanging massless and hypothetical particles nicknamed gluons — so called because they "glue" the hadrons together, and thus bind them tight.

If this is the case, then the strongest force known in the universe — that which binds the protons and neutrons in the nucleus together and is the source of the energy of the hydrogen bomb — may be only a pale reflection of considerably

Continued on p. 71

Jumping Jehoshaphat — It's a Nobel!

Among the formulas and notes on the bulletin board in M.I.T.'s Building 44 on the morning of last October 18 was a big letter "J" serving as the initial for four words: "joyful," "jubilant," and "jumping Jehoshaphat." The celebration was only a bit dampened by the fact that Professor Samuel C. C. Ting, who had just been announced as co-winner of the 1976 Nobel Prize in physics, was in Geneva, preparing experiments for the large accelerator at CERN, the European Nuclear Research Center.

When ~~Professor Ting~~ returned to Cambridge, (above, right) he was smiling from ear to ear, but he limited his public response to citing the many co-workers at M.I.T. and Brookhaven National Laboratory who had helped with the experiments which led up to the discovery announced in November, 1974.

left

Professor Burton Richter, who was at home in Stanford, Calif., when the news came, seemed "almost overwhelmed," according to Robert Cooke of the *Boston Globe*. "This is one thing that never happens in most physicists' lifetimes," he told the press (above, left). "I'm delighted, pleased, stunned, and surprised."

Professor Richter has been on the faculty at Stanford University since 1956, when he finished his Ph.D. in high-energy physics at M.I.T. He entered the Institute as a freshman in 1948, and all his degrees are from M.I.T. Professor Ting was raised in China, first on the mainland and later in Taiwan, before coming to the University of Michigan, his father's alma mater, to study physics in 1956. Professor Ting has been at M.I.T. since 1967, devoting most of his time to high-energy physics research and graduate-level teaching.

The Royal Swedish Academy of Sciences said that the experiments of Professors Ting and Richter, performed independently and reported simultaneously almost by chance, had revealed the existence of a fundamental particle of matter that is "something separate and new . . . A new field of research has been opened."

Professor Min Chen of M.I.T., one of Professor Ting's colleagues in the work leading to discovery of the J-particle, told Mark Munkacsy of M.I.T.'s student newspaper, *The Tech*, that "before November, 1974, no one took these ideas (about quarks and their special qualities of flavor, charm, and color) seriously; now everyone in physics is working on it. Physics has changed."

Science News speculated that the 1976 Nobel Prize established a record for speed between the time of discovery and time of the award. But Professor Richter had a modest answer: the fact that his and Professor Ting's identical findings resulted from two very different experiments performed independently represented "instant confirmation," he said. —*J.M.*

Toward a Normative Science

Technology/Society
by
Kenneth E. Boulding

A legend has it that science is a white knight who lives only in the valley of fact and that philosophy, religion, and the arts are beautiful damsels who live only in the valley of values.

Like most legends it contains only a glimmer of truth. Somewhere down the one valley are facts that are just so whether anyone likes it or not. Somebody once said the only verities in the universe are π and e, and these do seem remarkably impervious to human values. There is a story that a state legislature once decreed that π should be 3, both on the grounds that the Bible says so (the great tank in the temple was 10 cubits across and 30 cubits around according to I Kings, 7:23) and also because 3 would be easier for schoolchildren to manage. But neither human values nor wishes nor prayers nor legislation can make π equal to 3. Both measurement and mathematics defy every human value that might make them otherwise.

There is certainty in the realm of values, as well, though it is not so dramatic as π. Tertullian believed because to believe is absurd; so do we all, whether we believe in Christ or socialism or democracy, or even in science. Even the skeptic makes a leap of faith, "believing where we cannot prove," as Tennyson says. And the most absurd belief of all — that there is a "real" world — is shared by nearly everyone, because our values demand it.

As we pursue any value or fact, however, we skirt the valleys of science and values to find ourselves in a bog of ambiguity. Heisenberg showed that there is no physics without a physicist, no knowledge without a knower. Anthropologists perceive science as a subculture defined by its own values and helpless without them. It is a culture, for instance, which places a high value on veracity and curiosity, which political cultures and many folk cultures tend not to share. The water of the river of science flows from the great bog: there are no facts without perception and there is no perception without values. At all the gates of the mind there are censors, or so the perception theorists tell us.

All moral values rest on assertions of fact. The moralists build their fence with thou-shalt-nots, because they say on the other side of the fence are cliffs and unfriendly beasts, and so it is good to stay on the right side. Constantly they are questioned. People jump over the fences and push up the valley. Sometimes they do not return and are lost in the bog; sometimes they do return and say that the other side of the fence is not what we think, and we move the fence. This watershed domain is very large. Here values are constantly changed by changing perceptions of fact; perceptions of fact are constantly changed by new values. But the process is obscure and we constantly lose our way toward the higher ground.

I shall offer an outrageous proposal: we should drain the bog and build a city, and its name should be "normative science." Enough of valleys and bogs.

Normative science is the serious disciplinary study of the process of human valuation as an aspect of human learning and knowledge. It would pay particular attention to the meaning of our perceptions of whether things are going from bad to worse or from bad to better. It would study the dynamics of the world system and the relation of our perceptions to those dynamics. It would look at human decisions, which always involve a perception of better or worse alternatives. It would not be afraid to ask whether truth resides in perceptions of value, as it does (we hope) in perceptions of fact, though it might not come up with any easy answers.

The discipline of normative science would draw on the skills of many, perhaps most, of the existing disciplines. It could even begin with the forerunners of human valuation — valency in chemistry, preferences in animals. It would call upon genetics and physiology to study the construction of genetic values which are deeply involved in those patterns of behavior which it is no longer fashionable to call instinctual. It would command much from developmental psychology and from the study of human learning, which is certainly the core of the human valuation process. It would rely heavily on economics, which of all the social sciences perhaps comes closest to being a normative discipline.

It may be that, just as all science can really do is to tell us what is not true, and define the coasts of error that bound the vast continent of unknown truth, so normative science can only tell us what is not good, what is unjust, and what is not our duty, again bounding a great continent of unknown verities. But these boundaries are useful. The failure to understand them or to narrow them can get us into serious

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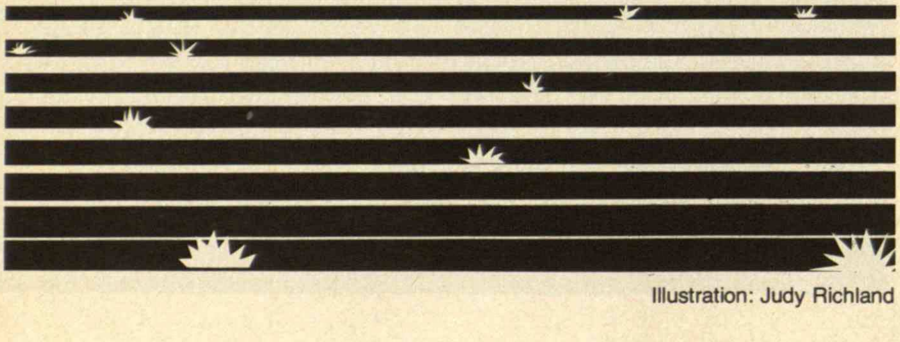


Illustration: Judy Richland

Science at the Hands of Carter and Congress

Washington Report
by
Colin Norman

When Jimmy Carter moves to Washington on January 20, a number of important science policy matters will await his attention. Though few of them are likely to rank high among Mr. Carter's political priorities, they are cherished by members of the scientific community. How Mr. Carter tackles them will have a lasting impact on the nation's science and technology.

The issues range from such fundamental matters as the erosion in support for many areas of research and development that has occurred over the past decade, to such nuts-and-bolts items as the appointment of top bureaucrats and advisers in Washington's sprawling science bureaucracy. The new president will also be faced with politically touchy nuclear policy decisions: whether to permit reprocessing of spent nuclear fuel and recycling of plutonium in power reactors, and whether to allow the liquid metal fast breeder reactor program to proceed at its present pace. Also ripe for a presidential decision is the question whether to reorder priorities in the nation's $2-billion biomedical research effort.

The election campaign yielded few clues to Mr. Carter's positions in those areas. Science was pushed aside for more important matters such as Mr. Carter's *Playboy* interview and Mr. Butz's racist remarks. Consequently, considerable uncertainty hampers the federal agencies responsible for science and technology. As the lame duck Ford administration goes through the make-believe of preparing a budget which will be swiftly revised by the incoming administration, many top officials are quietly looking for jobs.

Money and Power

There is at least one certain element in the new administration's science policy arrangements: Mr. Carter will have a science adviser who will also double as the head of the White House Office of Science and Technology Policy (O.S.T.P.). That much is assured by the fact that O.S.T.P. and the science adviser post were established earlier this year by an act of Congress, and it would require another act of Congress to get rid of them. What status the adviser will have in a Carter White House remains to be seen, however.

About the only clue we have so far is that, in response to a question from American Physical Society President William Fowler, Mr. Carter said that his science adviser would "provide a permanent and high-level relationship between the White House decisionmaking process and the scientific community." Since the question and answer were going to appear in the A.P.S. magazine *Physics Today* at the height of the campaign, he could hardly have said otherwise. A more tangible sign of the status of the office will be the expertise of the person Mr. Carter chooses to head it.

The present incumbent, Guyford Stever, has already signalled his intention to depart. As head of the National Science Foundation for four years and science adviser during the waning weeks of the Ford presidency, Dr. Stever has been a team player in the Republican administration, and he is generally regarded as having done an effective job in difficult times. Rumored to be in line to succeed him are Lewis Branscomb, head of research and development at I.B.M., and Harold Brown, President of California Institute of Technology. Either choice would be evidence that Mr. Carter intends to follow through on his promise to make his science adviser an important man in the White House.

Drawing: Mike Peters; United Feature Syndicate

One of the chief items on the agenda of Mr. Carter's science adviser will be to attend to the decline in purchasing power of budgets for science and technology, and the instability in funding for some areas of research. Though Mr. Ford's budget proposals for fiscal year 1977 treated science and technology relatively well, until that time, real support for science and technology had been steadily declining, to reach a level well below the peak of the late 1960s. Moreover, the past decade has witnessed large injections of funds in fashionable areas of research, such as environmental research, later superceded by energy research and development and cancer research, while other areas have been relatively neglected.

Though many of the scientists' complaints are exaggerated and more than a bit self-serving, there's some evidence that the erosion of support is being reflected in such indicators as declining innovation, patent balances, and so forth. A quick glance through the National Science

Board's latest report, *Science at the Bicentennial,* leaves little doubt of the depth of concern among the scientific community's top brass.

The report is a collection of letters from several hundred top research and development directors and laboratory chiefs. It lists declining government funding, particularly for basic research, as the top concern of the scientific community's leadership. All told, the report presents a gloomy assessment of the state of America's scientific enterprise. Complaints are directed to the growing bureaucratization of government research and development, excessive government regulations which have shifted research activities into nonproductive areas, and so forth. For sheer hyperbole, the letter of Dr. Harold Agnew, Director of the Los Alamos Scientific Laboratory is hard to beat. Growing bureaucracy and red tape "will in the not too distant future completely eradicate our nation's world position in research and technology," he suggested.

Thus Mr. Carter is inheriting a dissatisfied scientific community; it would be unrealistic to expect that his entry into the White House will rapidly dispel those concerns. Science and government will never return to the productive partnership of the 1950s and early 1960s. Accountability and government bureaucracy are established facts of life, and scientists, like everyone else, are going to have to live with them. But it will help to have somebody in the White House attuned to the concerns of the scientific community, as Mr. Carter claims to be.

Committee Shuffle

The new lineup on Capitol Hill is as unpredictable as the new presidential administration.

The House Committee on Science and Technology, which oversees the activities of such agencies as the National Science Foundation (N.S.F.), the National Bureau of Standards, and parts of the Energy Research and Development Administration, lost several members in the last elections. James Symington (D.-Mo.), the chairman of the subcommittee which has authority over N.S.F., gave up his House seat to run (unsuccessfully) for the Senate. A shrewd legislator, Mr. Symington has been a key defender of N.S.F. and has steered the agency through a minefield of right-wing attacks. But his loss will at least be partially balanced by the fact that one of N.S.F.'s most vocal attackers, John Conlan (R.-Ariz.) also gave up his house seat to run for the Senate. Another loss in the Science and Technology Committee is Ken Heckler (D.-W.Va.), who was defeated in a primary election for the governorship of West Virginia and failed to retain his House seat in a write-in campaign against the official Democratic candidate. Mr. Heckler was chairman of the subcommittee on fossil fuels. And finally, the committee's ranking Republican, Charles Mosher (R.-Ohio) is retiring at the end of this year.

Changes in the Senate are even more dramatic. Frank Moss (D.-Utah), Chairman of the Senate Committee on Aeronautical and Space Science, was defeated in his bid for a third term, and John Tunney (D.-Calif.), Chairman of a Commerce subcommittee on science and technology, was ousted by conservative S. I. Hayakawa. Both men were influential in scientific matters.

A particularly important development for scientific affairs is likely to be decided when the Senate reconvenes early in January. Under a plan proposed by a special select committee, the Aeronautical and Space Science Committee would disappear, and responsibility for most civilian research activity would be given to an expanded Commerce Committee. Energy research and development would be overseen by a revamped Interior Committee, and biomedical research would become the charge of a new Committee on Human Resources. Military science and technology would stay under the jurisdiction of the Armed Services Committee.

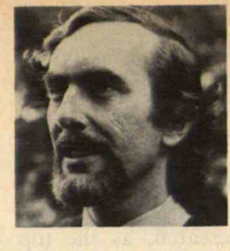
The reorganization plan is already foundering, since it would abolish several committees and subcommittees whose chairmen aren't eager to relinquish authority, but chances for some realignment of Senate committees are generally deemed promising. If the proposals are ratified, several new people will assume positions of power over scientific matters.

One committee that will probably be disbanded is the Joint Committee on Atomic Energy, which has dominated nuclear policies for more than a quarter of a century. The proposed Senate committee realignments would shift most of the joint committee's jurisdiction over nuclear development to the Interior Committee; alternatively, the House Democratic caucus advocates distributing nuclear policy among some four House committees. The joint committee is particularly vulnerable this year because five of its nine Senate members, including the chairman, John Pastore (D.-R.I.), have either retired or were defeated at the polls. The committee has also been attacked in the House for its staunchly pro-nuclear record.

So there will be many new faces in Washington's science policy circles. The next few months should be very interesting.

Colin Norman is Washington Correspondent for Nature *and a regular contributor to* Technology Review.

Economic Growth and Environmental Well-Being



Technology/Environment
by
Ian C.T. Nisbet

Environmentalists are often portrayed as being opposed to all economic growth, and hence in some way opposed to social welfare and "progress." The charge is fundamentally baseless, because all environmentalists — however frugal their habits — support growth in some sectors of the economy which they regard as socially beneficial. Where environmentalists differ from conventional economists is in the way in which they assess net social benefits. They examine with unusual thoroughness both the direct and indirect effects of economic activities, and in consequence are not so automatically enthusiastic about growth as their more traditional colleagues.

In hard economic times, it is easy for demagogues to oppose environmental measures as being anti-growth (or, worse, anti-jobs). But a look at the differences between conventional and environmental economics prompts a very different conclusion.

Chamber-of-Commerce Economics

Everyone wants to increase net social welfare, but a fundamental and unsolved problem in economics is deciding what activities contribute to this improvement. Conventional economic indicators such as the Gross National Product include all transactions which involve transfers of money. If one assumes that all economic activity conveys net benefits, growth in GNP must be a good index of economic advancement. This argument is sometimes referred to as "Chamber-of-Commerce Economics," as it is vigorously used by Chambers of Commerce to promote local economic growth. Despite its naïveté, it is still the basis of official economic policy in most countries of the world.

The argument has two obvious flaws, however: intangible (unmeasurable) costs and benefits are not included in the GNP; and much economic activity makes questionable or even negative contributions to net social welfare. For example, in Chamber-of-Commerce economics cigarette smoking brings almost unmitigated economic benefits. It provides income for tobacco farmers and their suppliers, processors, manufacturers, wholesalers, and retailers. If smokers fall sick, their medical treatment involves economic activity and those costs are counted into the GNP. Even when smokers die prematurely, this has little effect on economic activity, because most of them die near or after the end of their productive lives. (Indeed, to the extent that their premature death lightens the welfare burden, it would be counted in some schemes as a benefit.) Intangibles such as the pleasure experienced by smokers or the suffering of cancer victims are not included in this simple tally of benefits and costs. (But under an objective system for weighing intangibles, one would have to conclude that the former outweighs the latter, since smokers voluntarily assume the risks in order to gain the benefits.)

Of course, economists have long been aware of this basic confusion between costs and benefits, and a number of attempts have been made to devise economic indicators that will represent the net rather than the gross social effects of economic activity. However, only a few of the negative effects can be evaluated in numerical terms, and some of these elicit only minor modifications of the conventional GNP. The distinctive feature of environmental economics is that it demands the proper assignment of negative values to all socially harmful effects of economic activities, including intangible effects such as health and ecological costs, noise, inconvenience, and crowding. And in these terms cigarette smoking is clearly a net burden on society — and so, probably, are other economic activities which are less often questioned, such as the burning of coal, the raising of animals for meat, or the use of automobiles.

Another major difference between conventional and environmental economics is their treatment of resource depletion. Most of the genuine wealth of society is in the form of "hardware" (machinery, equipment, fertile soil, buildings, consumer goods, etc.). Although much economic activity involves "software" (education, communications, recreation, etc.), it is in general dependent on the flow of materials and energy through society. Only a mild caricature of our economic system would say that it functions primarily by extracting materials from the ground, using them for varying periods, and ultimately returning them to the ground as wastes. (Some of the wastes go into air and water also, as pollution, and we are working hard to rationalize the system by transferring these wastes back to the land where they really belong.) Each step in the flow of materials through the economy requires the use of energy — in most cases fossil fuels — and the materials are ultimately discarded in a state of higher entropy than that in which they were extracted.

This process of destruction and degradation of natural resources — which economists quaintly choose to call "production" — is a primary concern of environmentalists. In Chamber-of-Commerce economics, rapid flow of materials and energy is regarded as providing benefits throughout the economy; hence "industrial output" is a leading economic indicator. Environmental economists, on the other hand, argue that genuine wealth is generated by using materials, not by degrading them or discarding them: hence reuse and recycling are better than consumptive uses. Any net flow of material ("throughput") represents depletion of a basic resource and should therefore be regarded as a cost to the system. In the words of E. F. Schumacher: "Since consumption is merely a means to human well-being, the aim should be to obtain the maximum of well-being with the minimum of consumption."

Discounting the Future

The reason for regarding throughput as a cost to the system is that the consumption of materials depletes nonrenewable resources and thus limits future options. Conventional economics treats the problem of resource depletion by pointing out that rising prices of dwindling materials will reduce demand and stimulate the development of substitutes. Environmental economists retort that "reducing demand" represents a reduction in future opportunities, and that for many materials (including fossil fuels and certain scarce minerals) there is little prospect of finding substitutes at acceptable costs. For

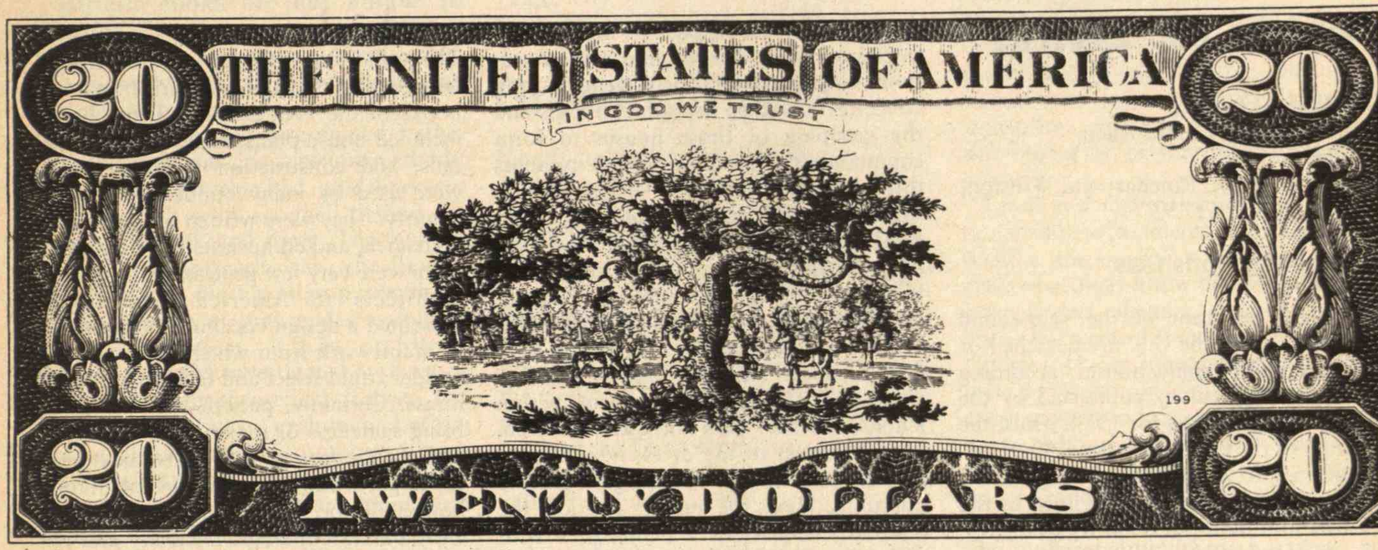


Illustration: Judy Richland

many minerals known world reserves are sufficient for only a few decades at current rates of use, so the options being foreclosed are those of the next generation, if not of our own.

The problem of resource depletion is only one facet of the general problem of discounting the future — weighing present benefits against future opportunities. Of course, people do discount the future severely. Almost every action we take, from crossing the street to choosing a marriage partner, involves a more or less conscious weighing of immediate gratification against future security. Economists who study such behavior find that individuals typically discount delayed benefits at an annual rate of 10 per cent or more. This is the economic justification for many activities that degrade the environment.

But the concept of a discount rate fails in some very important cases. No one would choose to have children if the benefits they provide were truly discounted at a 10 per cent annual rate. For genetic reasons that transcend economics, we value each of our children at least half as much as we value ourselves. Hence, when we weigh economic activities which would limit the opportunities of future generations, a high discount rate is inappropriate. Environmental economists would argue that the discount rate should be very low, zero, or even negative for certain irreplaceable resources, such as works of art, unique natural assets, endangered species, or in some cases reserves of minerals with no foreseeable substitutes. For the same reason, we should assign a very high notional cost to activities which may impose burdens far into the future, such as the generation of long-lived radioactive wastes.

Environmentalists emphasize the externalization of costs. Pollution, for example, is the disposal of wastes into the general environment to the benefit of the polluter, but to the cost of external parties who use the environment. Much of the work of environmental economists involves devising systems — regulations, incentives, taxes, subsidies, etc. — to induce polluters to internalize these costs. While this work has had some success in cases where external costs are localized and readily measured, the problems are much more difficult where the costs are disputed, difficult to evaluate, long-delayed, or widely dispersed. Although controlling pollution is in principle the simplest problem in environmental economics, it is proving remarkably intractable in practice.

Given these major concerns of environmental economists, we may return to the question of growth. Environmentalists do not oppose growth *per se.* However, their views on the relationship between economic activity and net social welfare are so radically different from those of conventional economists that they frequently find themselves opposing growth in sectors of the economy whose benefits are usually taken for granted. The polarization arises because environmentalists place high value on factors (including health, aesthetics, the natural environment, and the welfare of future generations) that are usually ignored as unquantifiable by conventional economists. In the words of H. Daly, environmentalists seek growth "in things that really count, rather than in things that are merely countable."

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Book Reviews

Design for Living

The Place of Houses
Charles Moore, Gerald Allen,
Donlyn Lyndon
New York: Holt, Rinehart and Winston,
1974; 278 pp., $17.95

Reviewed by Doris Cole

Sixty-eight per cent of the year-round housing units in the U.S. are detached or attached single-family houses, according to the housing survey conducted by the Bureau of the Census for 1974. Thus, the majority of the population lives in houses.

Contrary to what we see in large cities, contrary to the reported declines in the construction industry, contrary to the rise in costs of land and building materials, the statistics demonstrate that a significant number of people still buy, sell, build, and live in houses. Though a man's home is decidedly less than a castle these days, the American dream still foresees a house and the American way of life (perhaps more than in any other western country) still includes a house. As a result, this book treats a subject which is immediately relevant to a surprisingly large number of people throughout the United States: the subject of houses is not trivial, nor is the product yet an unreachable luxury for most of us.

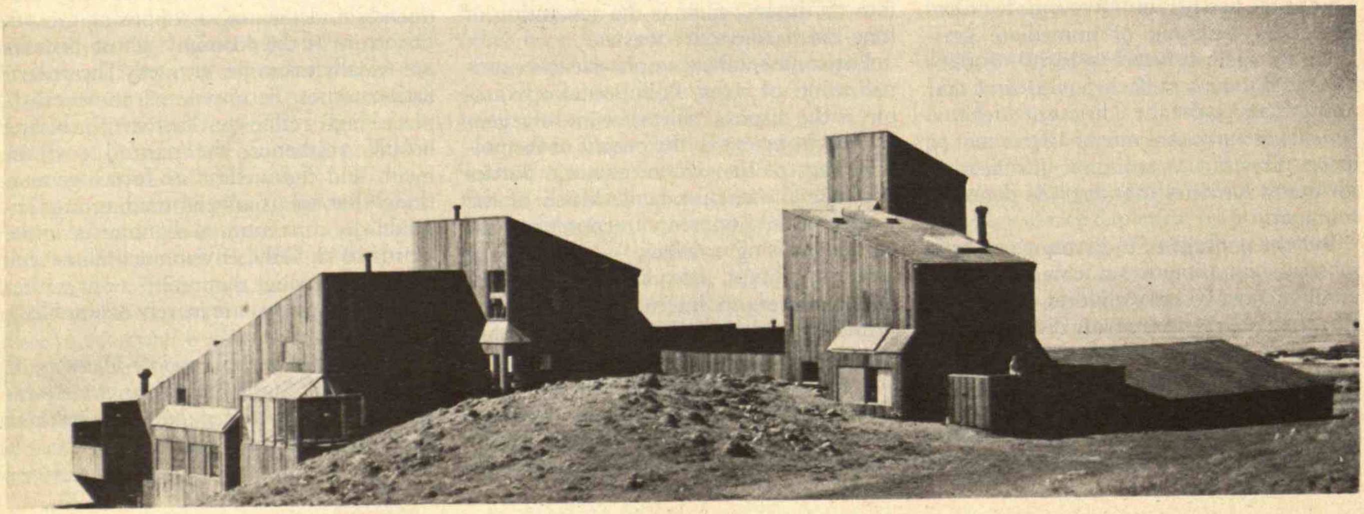
The reader can expect to find a well-organized book divided into several sections covering the diverse elements and concerns related to individual houses and the grouping of those houses to form communities. The first section presents three examples of towns — Edgartown in Massachusetts, Santa Barbara and Sea Ranch in California — which have very different architectural styles, geographic locations, and historic settings. Also included is a discussion (with photographs) of the work done by the firm Moore Lyndon Turnbull Whitaker (M.L.T.W.). Later, the possible plan arrangements within a house and sites for a house are reviewed, with attention to the diversity and complexity of these seemingly simple questions. Next, the authors consider the separate elements of a building — windows, doors, stairs, entries, fireplaces, and so on — that define the character of the houses we inhabit. The book provides a lengthy checklist for prospective householders with numerous questions about the daily patterns of our lives: how we cook our food, wash our dishes, entertain our friends, brush our teeth, and sleep in our beds. And finally, the authors make an eloquent plea for "the genuine community of assent and common understanding that makes for a larger sense of place," for concern not only for our own individual houses, but also for the larger world which we all inhabit together.

Household Etiquette

The authors' stated goal is a modern pattern book based upon American pattern books of the 19th century. Those books included house plans, façades, design details, and construction techniques, and were used by many builders across the country. They were written by carpenters, craftsmen, and enthusiasts at a time when there were very few professionally trained architects in America. The books presented a design vocabulary, an aesthetic framework from which the client and builder could select and fashion a suitable house. Certainly, pattern books did not bring sameness or mediocrity: from such books were formed the handsome houses of Edgartown, the graceful plantation houses of the South, and many of our early public buildings. Diversity and imagination were guided and aided by these books to create a harmonious and cohesive whole within our towns and through the countryside.

Another sort of early pattern book is the so-called "etiquette" books written and read primarily by women. One of the finest examples is *The American Woman's*

Sea Ranch, an oceanside housing development designed by Moore Lyndon Turnbull Whitaker in California. (Photo: Morley Baer)



Home by Catherine Beecher and Harriet Beecher Stowe: it presented very detailed and explicit instructions on how to design, build, and live in houses to promote our moral well-being. These women explored in detail the siting and orientation of houses to give the occupants fresh air and sunshine for better health. They presented a thorough analysis of stoves and chimneys to avoid unhealthful drafts and wasted fuel. They suggested plan arrangements to aid women in caring for their children while performing the daily household tasks. In all their concerns their goal was to enhance the physical and mental well-being of the occupants, to create good citizens for our country.

Pattern books are not unique to America. They have existed in all countries and are essential to architecture. Whether written as guides for the layman or treatises for the artist, these books explained, codified and investigated aesthetic principles and construction methods. The ancient Greeks had guidelines for their temples, with accepted designs for column, capital, and frieze. The builders of the Medieval cathedrals, the Renaissance palaces, the Egyptian pyramids — all had written or oral guides to follow. The 16th-century Italian architect, Andrea Palladie, investigated systems of proportion in his theoretical treatises. The 20th-century Swiss architect, LeCorbusier, also investigated proportion with his "modular man." Throughout history it was from such guides that architectural design principles were communicated, debated, followed, and modified.

Visual Literacy

The Place of Houses does not include the design and construction detail, the theoretical sophistication, or the moral fervor of the earlier books, but it does cover some of the same concerns and issues and follows the same traditions as far more than just a picture-book of houses. It is not so explicit or forthright as the historic pattern and "etiquette" books, but does present the philosophical approach held and practiced by the authors. The questions asked or ignored, the information included or excluded, the examples used, the emphasis on movement, the definition of rooms as empty stages, the very organization of the book gives us their point of view: high ceilings, exposed structures, sloped roofs, 45° angles, weathered wood, and complicated multilevel spaces are clearly preferred.

This design vocabulary is used by other contemporary architects, as well, but it is only one approach and it is not necessarily advocated or practiced by all architects today. In fact, many architects would disagree with both the questions and solutions presented by the authors. Consequently, the reader should not misinterpret the book's content as the accepted vocabulary of the profession.

Given the poor quality of manufactured goods, the condition of cities and suburbs, the ubiquity of trash and billboards, and the number of slums, one might wonder whether *The Place of Houses* is a review of architecture and design or an introduction. Reading, writing, and arithmetic are perhaps the basic skills, but the goal of visual literacy should have priority, as well. This book, among others, could serve well as a basic primer.

Doris Cole is an architect for Architecture/Engineering and Construction Services, Physical Plant, Massachusetts Institute of Technology and author of From Tipi to Skyscraper: A History of Women in Architecture *(Boston, i press, 1973).*

Growing Pains

Health and Industrial Growth
Ciba Foundation Symposium 32
New York: Elsevier Excerpta Medica,
North Holland, 1975; xiii + 267 pp.,
$18.50

comment

Reviewed by Jeanne M. Stellman

What is the effect of industrialization on the health of people in developing countries? Are the environmental and social needs of the Third World met, ignored, or perhaps even exacerbated by industrialization?

One example of the experience of nonindustrialized countries suggests we have little reason to be optimistic. The most pressing public health problems in Ghana are perhaps typical of other Third World countries: undernutrition, malnutrition, and inadequate drinking water, sanitation systems, and housing. With industrialization, the people of Ghana now face pollution, disruption of their towns and villages, population resettlement, and possible deterioration of their natural resources.

In the early 1960s, the Volta River Dam Project was carried out to generate hydroelectric power — not for rural electrification, but for aluminum smelting and exploitation of bauxite resources. Volta Lake was created and now occupies 3.6 per cent of Ghana's land area. The development precipitated a vastly increased incidence of waterborn diseases, destruction of 739 villages, and disruption of 80,000 people's lives.

Schistosomiasis, a severe, waterborn kidney and bladder ailment, rose from an incidence of 5 per cent to 90 per cent. In addition, a new scourge, tuberculosis, was introduced to the migrant workers who were housed in unsanitary shanty towns. Many of the bauxite miners developed silicosis and tuberculosis as a result of their dusty work places. And given impoverished living conditions and poor nutrition, tuberculosis soon became widespread.

Industrialization brings still other afflictions to developing countries. Agricultural industries have displaced food crops for such commercial crops as tobacco, cocoa, and cotton, and serious nutritional deficiencies have developed as a result.

No International Standards

Clearly, indigenous health problems are worsened, not relieved, by industrial and agricultural "development." I think we can conclude that the purpose of such development is not to improve the human condition. Unfortunately, until a country reaches a fairly advanced stage of development, the combination of overwhelming public health problems and the small percentage of the population involved in industry makes occupational health almost irrelevant. In contrast, the two industrialized Asian countries having the highest per capita income, Japan and Singapore, consider job-related deaths and diseases to be very relevant and very serious.

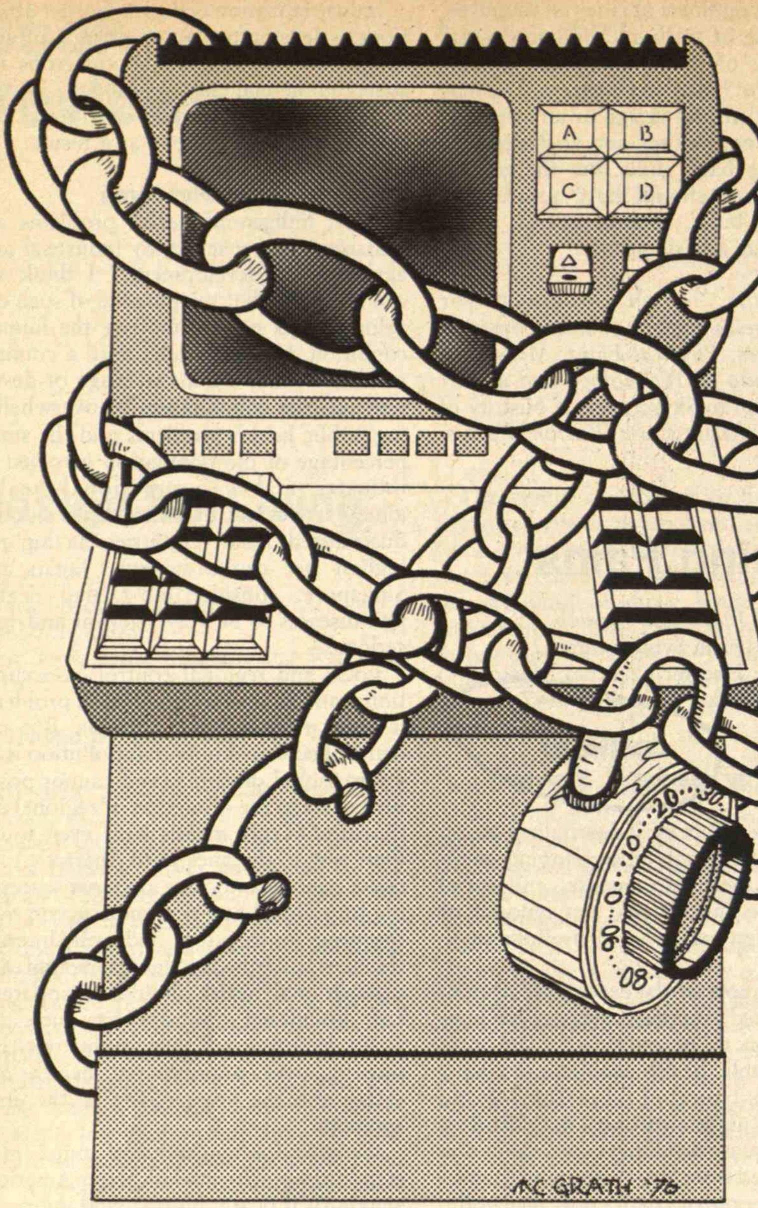
Local and regional control of occupational and environmental health problems is often proposed as a solution. But students of ecology know that pollution is an international dilemma, and cannot possibly be left to the discretion of regional authorities. (Trace metals have even found their way to the once-pure Antarctic.) Because regions and cities are most susceptible to political and economic persuasion, the need for national and even international standards for environmental and occupational health should be apparent. Left unfettered, industry has time and again demonstrated that productivity has priority over occupational health and safety and the preservation of the environment.

Clearly, foreign industry must meet standards which equal or better American standards if death, disease, and injury are to be avoided. American industry already claims 16,000 lives and injures at least 25 million workers a year. Countless thousands of people suffer diseases induced by toxic exposure, and the list of known side-effects of industrial chemicals continues to lengthen. Since Third World workers are not so well-trained, healthy, and educated as American workers, there is no reason to expect they will fare any better than their American peers unless stricter controls are adopted.

Technological Imperialism

Most nonindustrial countries are plagued by booming population. Experience has shown that an improved standard of living curbs population growth. But the rape of poor countries by commercial interests does not raise the standard of living and often disrupts extended family structures. There is no reason to expect industrialization itself to slow population growth.

Just how does one tackle the health problems of the nonindustrialized world? Several contributors to this book praise



the "barefoot doctor" approach attempted on mainland China. Others, notably Ivan Illich and J. R. Philip, urge coping with the cruelties of nature and doing with fewer luxuries (advice hardly appropriate to people who have no luxuries and no choice but to cope).

No one has the answers, but surely more exploitation and cultural disruption are not the solution. Let us stop to make rational decisions based on human priorities before technological imperialism gets out of hand. And who knows? If a more cautious approach succeeds abroad, we may even adopt it at home.

Jeanne M. Stellman is Clinical Associate Professor in the Department of Research Medicine at the University of Pennsylvania.

Protecting Bits and Bytes

Security and Privacy in Computer Systems
Lance J. Hoffman, ed.
Los Angeles: Melville Publishing Co., 1973; ix + 422 pp., $18.75

Reviewed by Malcolm L. Stiefel

This book is a collection of 21 articles (all but two are reprints) dealing with the design of secure computer systems. The papers, dating from the 1960s and early 1970s, have been used as supplementary readings for undergraduate computer science students. Most of the selections are excellent, covering fundamental security problems as they are perceived by some of the leading specialists in the field.

An understanding of computer security problems is important not only for the student, but also for the system designer and the user. The Privacy Act of 1974, which establishes some elementary rules for the dissemination and maintenance of personal information held by federal agencies, has finally stirred some awareness in the private sector. It is fair to assume that more restrictive measures are coming on the federal level — dozens of bills are already under study — and some privacy-oriented legislation is bound to be aimed at businesses in the coming months.

But the user who sees the light and decides to augment his system's security will find his options perplexing, at best.

To begin with, present interest in the security problem and solutions to it seem to be focused on the computer room itself or on the remote data terminals. But the design must address the entire *information system* — including the people operating the equipment, preparing the data, and using the output — of which the computer is only a component. The narrower view often ignores the enormous human impact of data security, not only from the standpoint of privacy, but in terms of safety, operability, and integrity, as well.

Integrity — the need for a system to be safe from physical compromise — shouldn't be concerned only with guaranteeing a lock on every keyboard, guards at exits, smoke detectors, scramble circuits, uninterruptible power systems, and closed circuit television. Integrity must extend to the procedures for using the data in the information system, and to the means of ensuring that the data base is accurate. What good is it to provide elaborate protection for meaningless data? Of what value is a tamper-proof data center if errors render the system useless?

The problem is universal in data processing applications. The losses suffered by businesses as a result of the inadvertent errors made by data processors are estimated to be at least an order of magnitude higher than losses due to fraud. Known computer-related fraud losses in 1974 amounted to $200 million, and observers estimate that only 15 per cent of the cases were reported. If the unreported cases involve an additional billion or so, we have roughly $1.2 billion a year in criminal loss, but perhaps $10 billion or more in losses triggered by unintentional human error.

Of course the user cannot ignore criminal precautions entirely. But a review of the methods for handling, storing, and disposing of printouts, data entry forms, and other material related to the data processing function is likely to yield more significant benefits. If the opportunities for misplacement or incorrect routing of data can be reduced or eliminated, the security of the entire company, let alone its computer center, is enhanced.

Unfortunately, an assessment of the relative weights of threats from outsiders and errors from within is missing from Dr. Hoffman's book.

An Infant Art

If system integrity can be established and maintained, the designer faces still other dilemmas in trying to make intelligent choices among alternative schemes to improve the security of his system. At present, there don't seem to be any commonly accepted quantitative performance requirements to assure the security of information systems. The book advocates "measures for evaluating the effectiveness of data security techniques in various . . . . environments; methods for estimating the costs of implementing the safeguards in various classes of information systems; and tradeoff relationships between these and other relevant variables. Equally important is the ability to estimate potential losses . . . . The design criteria for data security systems include effectiveness, economy, simplicity, and reliability." Agreed. Yet, we seem to have made headway only in determining costs — hardware, software, and operating costs — of specific designs.

The fact is, this ability to specify meaningful performance parameters is characteristic of mature disciplines; the art of providing data security is still in its infancy. Standards for computer security and checklists for their implementation abound; there's one in Dr. Hoffman's book, as well. But this approach doesn't go far enough. How, for example, does one determine the relative merits of two different file protection schemes, short of expensive, exhaustive testing over a long period of time? What will be measured? Certainly, the penalty in response time, and the dollar cost of implementation will be considered. But what about a measure of the probability that the protection mechanism will fail in a given instance, due, say, to hardware failure, or due to human error?

We may rest assured that tools can be devised to answer our questions. The problem is, we still don't quite know what to ask. That's where progress must be made.

Malcolm L. Stiefel, a senior systems analyst with Keystone Custodian Funds in Boston, has dealt with military command and control systems, hospital information systems, municipal information systems, and investment accounting systems in his 17 years as consultant, systems engineer, programmer, and writer. He received the B.S.E.E. from the Polytechnic Institute of Brooklyn in 1959, and later was a graduate student at M.I.T.

Letters

Continued from p. 4

The "horn-like" projections observed on Nessie are probably not horns. Turtles do not have horns, and for an animal that pursues fish, the need for streamlining would make such a frivolous adaptation unlikely. If not horns, then perhaps probosci. These would aid in breathing while almost completely submerged and could be pressed against snout when diving to reduce drag. As it happens, the soft-shelled turtle is a living example of this sort of adaptation by a turtle. The soft-shell also has a very long neck. I have seen it extended so that the distance from snout to carapace nearly equals the carapace length. A rapaceous beak and large, thick tongue are also turtle characteristics. The sea turtles, especially the leatherback (body length over eight feet, weight up to 1,500 lbs.) have flippers very similar to those figured in the *Review.*
Richard H. Fillon
Dartmouth, Nova Scotia

Dr. Fillon is affiliated with the Atlantic Geoscience Center of the Geological Survey of Canada, Bedford Institute of Oceanography. — Ed.

Pencil and Paper Arithmetic

I read with interest Robert R. Beck's letter *(October/November, 1976, p. 5)* about popularizing mathematics.

People need mathematics to manage their everyday lives, but computers are not the way to popularize mathematics. Because of pocket calculators, we are already forgetting what little math we know. We really need to get back to basic pencil and paper arithmetic.
Richard J. Alden
Sunnyvale, Calif.

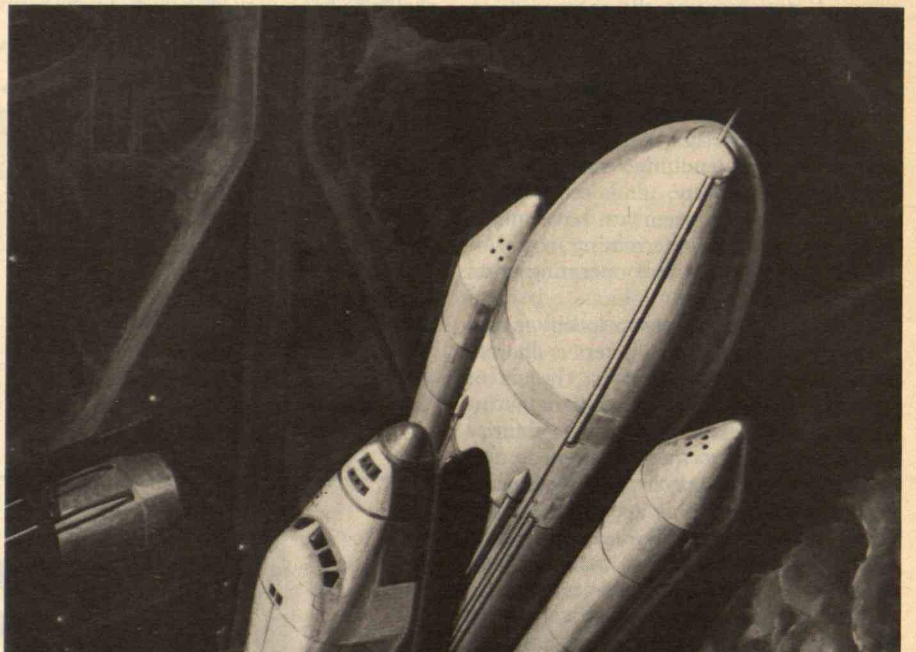
O.T.A. and Military Procurement

George Boehm notes the Office of Technology Assessment's failure to review military procurement *(O.T.A.: Time to Question, May, 1976, pp. 10-11).* Perhaps one reason is that another congressional office has been performing this function for the past seven years.

The Procurement and Systems Acquisition Division of the U.S. General Accounting Office annually issues reports on the status of about two dozen military acquisitions, providing comments on cost, schedule, and performance. A good many reports will be classified, but some general views have been published in reports available to the public, as well as in congressional testimony.
John G. Barmby
Washington, D.C.

Trend of Affairs

Trends This Month



When the Space Shuttle lifts off in 1981, N.A.S.A. will be writing contracts with firms and institutions for space on board. And the cost may be as low as a $10,000 "get-away special." (Drawing: Rockwell International Space Division)

SPACE

Space Shuttle: Now Accepting Reservations

First there was the air mail service. Then came Amtrak and Conrail. Now the U.S. government is about to enter the most exotic transportation business of all: earth-orbiting scientific and sightseeing missions aboard the Space Shuttle.

Reservations are being booked and tickets are on sale. For $10,000, N.A.S.A. will contract to carry your black box (up to 200 pounds and five cubic feet) into space and bring it back again; for about $18 million, you can charter an entire Shuttle flight (over 60,000 pounds of freight and up to four passengers).

The $10,000 "get-away special" (a phrase used by James C. Fletcher, Administrator of N.A.S.A.) is a price most customers will never see on their invoices. It covers transportation only ("Screw you down, take you up, and bring you back") for an experimental package which requires no services and no utilities and which is guaranteed not to disrupt any other experiments on board.

But Dr. Fletcher uses the example to emphasize that the Space Shuttle will put N.A.S.A. in the transportation business. By 1981, when regular flights begin, N.A.S.A. will be writing transportation contracts "for a firm, fixed price set at the time of contracting, and the launch will be guaranteed," said Dr. Fletcher at the 27th Congress of the International Astronautical Federation in Anaheim, Calif., last fall.

Just as with any other transportation contractor, low cost will be the name of N.A.S.A.'s game. The Space Shuttle is inherently lower in cost per unit of transportation than any previous space vehicle: its major components are reusable, and when the program is in full operation each Shuttle is expected to be refurbished and ready for relaunch within 14 days of its previous landing; major overhaul will be required only after some 60 missions.

Other sources of economy built into the Space Shuttle concept were listed for the I.A.F. by C. M. Lee of N.A.S.A.:

— The Shuttle is fully standardized from its racks and pallets for experiments to its power inputs and data outputs.

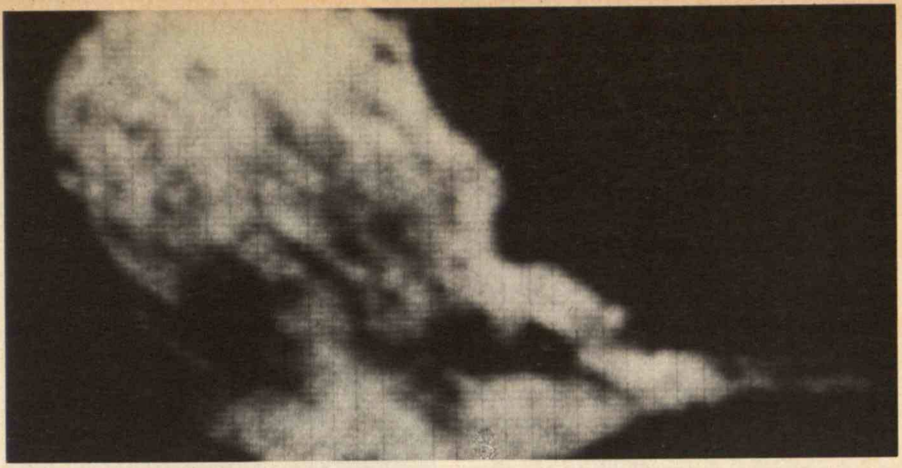
— Shuttle space will be sold at standardized rates, so much per pound, so much per unit of power required, so much for data storage and transmission.

— The Shuttle crew will have no responsibility for experiments; their tasks will be repetitive, and training needs will be minimal.

— N.A.S.A. will provide only transportation and support services; the user will be fully responsible for the design and operation of his payload. This policy eliminates, at least from N.A.S.A.'s budget, a major responsibility previously assumed by the space agency.

— Shuttle flight plans will be standardized. Once calculated, such mission elements as consumables, thermal factors, power requirements, and trajectories will be repetitive, and mission planning will therefore be simplified.

All this sounds down-to-earth, as if a Shuttle flight in 1985 would be as routine as today's 747 departure for Honolulu. But an element of Buck Rogers is inescapable: over 500 Shuttle launches are postulated for the decade of the 1980s, up to 60 in a single year. — *J.M.*



A new radar map of the surface of Venus, made last summer, reveals this irregular area of "considerable structure" — a rough but defined surface suggesting the work of internal, tectonic forces. No other planet except Earth is known to display features quite like this, and since Venus also shows what appear to be ancient impact craters, Professor Gordon H. Pettengill of M.I.T. says it is "a class unto itself." This picture is an enhanced image from a radar map with a resolution of 22 kilometers made at the Arecibo Observatory by Drs. Donald B. Campbell and Rolf B. Dyce of Cornell University working with Dr. Pettengill.

Clouds Hide a Rugged Venus

The remarkable Viking discoveries on Mars have eclipsed some just as remarkable discoveries during the past six months about our nearest celestial neighbor, Venus.

Venus is cloaked in cloud, its surface invisible. But we now have a map of that planet between latitudes 45° and 75° whose average resolution is about 22 kilometers (meaning that features as small as perhaps twice that size can be distinguished), and better maps will soon come.

Improvements at the Arecibo Observatory (Puerto Rico) completed in 1975 turned that instrument into a radar-camera which can achieve much improved definition — in theory a resolution of four kilometers near Venus' equator. Using this new instrument and a satellite receiver located in a valley six miles away, Drs. Donald B. Campbell and Rolf B. Dyce of the National Astronomy and Ionosphere Center at Cornell University and Professor Gordon H. Pettengill of M.I.T. obtained the first detailed, comprehensive radar images of Venus.

These images show what seems to be a large impact basin, much like those we see on the moon. But they also show Maxwell, a well-defined region the size of Oklahoma whose surface appears to be composed of ridges and valleys, apparently the result not of bombardment but of internal, tectonic activity.

While Mars and possibly Venus also show evidence of past tectonic activity, the well-defined, high-contrast, radar-bright regions seen on Venus have no parallel there. Thus Venus "seems to be a class unto itself," Dr. Pettengill told John Noble Wilford of the *New York Times* shortly after the results were first published in *Science* (September 17). — *J.M.*

Laws for Spacekind

Most lawyers seem to have all the answers. The space lawyer has only questions. Yet to be determined are: who has space rights over a country; who can lay claim to the moon, or for that matter, the rest of the universe; who holds rights to the energy of the sun; what citizenship for the residents of space colonies; whether patents are valid in space, and on ad infinitum.

Space law has been a legal specialty since the 1950s, well before the United Nations adopted what is now commonly called the Outer Space Treaty assuring freedom of all nations to participate in space activities and prohibiting warfare from outer space. Since then, there have also been international agreements on the rescue and return of endangered astronauts, on the liability of a nation for damage that can be traced to its space programs, and on the registration of all objects launched into space. And there have been countless hours of debate in United Nations committees and subcommittees about the legal implications of such futuristic enterprises as power satellites, lunar mines, and space colonies.

Earth resources satellites have raised legal issues that may be nearing consensus. Ronald F. Stowe of the U.S. State Department believes most nations agree that satellites studying weather and earth resources should fly without limitation, and that the data they return should be fully disseminated. But nations scrutinized by orbiting sensors should expect interpretations of the data on their resources before anyone else.

International debate has hardly begun on a host of other issues in space law. Solar energy, for example, presents a special problem because some nations have more of it than others. If a nation can claim no land between 40° N and 30° S latitude, it is as impoverished with respect to the sun as a landlocked nation is with respect to the sea. Hence the argument by Aldo Armando Cocca, Argentina's Minister of Foreign Affairs, at the 19th Colloquium of the International Institute of Space Law last fall: solar energy utilization "shall be carried out for the benefit of the whole of mankind, irrespective of geographical location of states."

The orbit 36,000 kilometers above the equator especially attracts astronautical engineers. There, a satellite is stationary above the earth's surface, and radio transmitters and receivers can be fixed on it. In 1975, Colombia lay claim to the geostationary orbit above its territory, proposing to collect levys on all satellites using it.

Colombia's claim is clearly inconsistent with the 1967 Outer Space Treaty's emphasis on the free use of space. But international law in whatever sphere has to be consistent with the realities of national sovereignty, said V. S. Vereshchtin of the U.S.S.R. Institute of State and Law.

What of the resources of the moon and planets? The first draft of a treaty for the moon was written in 1972 by a United Nations committee, and lacks agreement on only one major issue. All nations seem willing to regard lunar resources as a "common heritage of mankind," so that no single nation has the right of unilateral exploitation. And as in current Law of the Sea negotiations, profits from lunar resources are to be assigned to an international body, as yet undefined, to be used for international purposes — also undefined.

The bone of contention is whether a moratorium on lunar resource development should be declared until such an international body is established. The U.S. opposes a moratorium, contending that the first priority should be exploration and development.

G. S. Robinson of the Smithsonian Institution believes all these questions give space law a horizon much too small. The conditions of life in space will be very different from those on earth, and "earth-alien cultures" will breed a new kind of race — "spacekind," Dr. Robinson calls the breed. To avoid the "repetitive violence attending colonialism," spacekind will need wholly new, sensitive legal regimes. The ultimate test of space law will be how well it helps space colonists escape the frustrations and conflicts of terrestrial man. Dr. Robinson's proposal to the I.I.S.L. is a "Convention of Spacekind" to assure "independent cultural and political integrity" for inhabitants of space.

If these speculations seem uncharacteristically futuristic for the legal profession, they are. For 20 years space law has been ahead of space technology, hypothesizing problems which man could not yet have — and may never have. An air of unreality seemed inescapable at the I.I.S.L. last fall.

Nonetheless, Institute members argue to keep law ahead of technology so that the consequences of technological progress in space can be assessed and perhaps controlled. But they confront a dilemma, since it is difficult to pose potentially real problems in the abstract. If the concept of exploiting lunar minerals by a space colony is hardly more than serious science fiction, then laws to govern that exploitation can hardly be more than fiction based on fiction. Only as a space colony is prepared for orbit will the real legal issues it presents come alive, and then even the best-intentioned debates and treaties will suddenly have unexpected dimensions. — *J.M.*

TECHNOLOGY ON THE MARKET

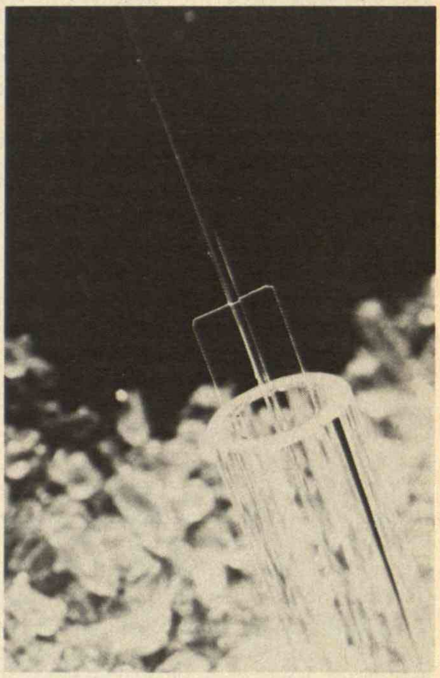
Boom Years for Fiber Optics

According to a new market research report, an enormous increase in glass fiber cables is expected over the next several decades. The recently developed hair-thin glass fibers promise to replace conventional copper wires for communications (*see March/April, 1976, p. 16*). The super-transparent fibers can carry thousands of phone conversations and other communications on beams of light, and are cheaper than copper cables.

The report by Gnostic Concepts, Inc., a California market research firm, predicts that by 1990 glass fiber cables will have made significant inroads into the copper cable market, generating an $883 million a year industry in the U.S. The study, reported in the October, 1976, issue of *Optical Spectra,* predicts a world market of $10 billion by the year 2000.

Because the optical fibers are secure against outside monitoring, the military will be their first heavy users, said the report. This early market, and the promise of huge commercial markets, will encourage further development and price reductions over the next few years; by 1990 commercial uses are expected to predominate.

Optical fibers will first appear commercially as connections between telephone



The three components of a single-material optical fiber — the central rod, supporting plate, and tubing. To produce the finished fiber, the assembly is heated, collapsing the tubing, and drawn into a single filament the diameter of a human hair. Mass production using such techniques will greatly reduce costs, and allow glass fibers to take over the majority of new communications links by the year 2000. (Photo: Bell Labs)

exchanges in urban areas, where they will ease the severe congestion of underground cables. As copper prices rise and optical fiber costs fall, the recovery of scrap copper from old cables will pay for the cost of new optical fiber cables, said the market researchers. However, most optical fiber installations will be either in new systems or to supplement existing cables.

U.S. demand will represent about half the world total, said the report, and the demand will be met almost entirely by U.S. production. — *D.M.*

Digital Dodo

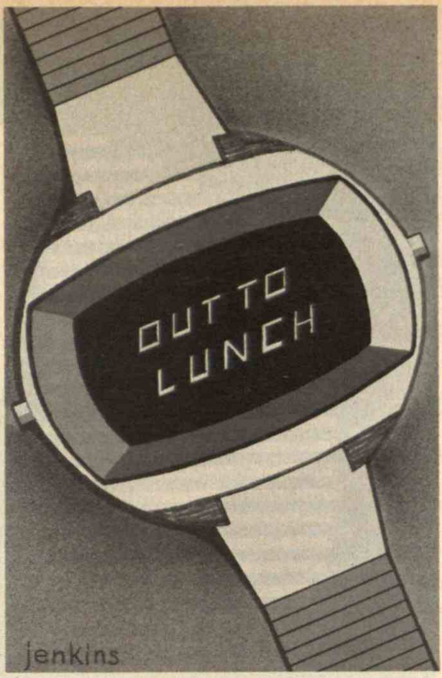
For a while, it appeared as if our headlong race into the 21st century would be timed with a digital watch. The electronic devices are being turned out by the millions and snapped up by buyers. But lately indications are that the digital watch is but a fleeting craze, and the bright, blinking watch faces will vanish with platform shoes and pet rocks.

One sign is a survey of digital watch owners conducted by *Consumer Reports* (November, 1976). Although the 635 digital watch owners who answered the magazines's questionaire were by no means a random sample of owners, their disillusionment revealed several drawbacks that are perhaps widely felt.

Many complained that the digitals are hard to read. One type of display, the Light Emitting Diode (LED), depends upon a button which is pressed to light the numerals and tell the time; each button press drains the watch's battery. The other type, the Liquid Crystal Display (LCD), is visible without button pressing, but is impossible to read in the dark, for the display issues no light of its own. Manufacturers of both types of watches are trying to surmount these disadvantages, but according to *Consumer Reports,* each innovation presents fresh problems. For instance, some manufacturers make an LED watch that lights the numerals at the flick of a wrist. Many owners have been irritated to discover that the watch lights inadvertently, needlessly draining the batteries. LCD watchmakers have built watches that feature a light to illuminate the display in the dark, but they require an extra battery and some button-pushing.

The digital owners surveyed had still more damning complaints: more than half made negative statements about the sturdiness of the watches. Strong electromagnetic fields, as are generated by loudspeakers and the electric doors of a commuter train, cause the watches to go berserk, reported owners, and heat and cold can be disastrous to accuracy.

Problems with battery replacement also brought complaints. A person who presses the button of his LED watch 20 to 30 times a day will have to replace the $5 battery every two or three months, said



The digital watch may be a bright idea that fizzled, as many consumers find it more a bother than a convenience. (Drawing: Tom Jenkins)

one industry spokesman. Many owners are annoyed by lengthy delays in simple repairs. Replacing the battery often requires help from the dealer, and weeks can go by while the watch shuttles to and from the factory.

The owners also reported basic problems with telling time digitally. Most people are unused to reading numerals rather than clock hands, and must make abstract calculations to figure out time intervals that are visually represented on the conventional watch face. Timing events with an LED digital watch is difficult if the wearer has to keep a button pressed. And setting a digital watch usually involves more complex button-pushing or other manipulation than does setting a conventional watch.

One digital watch owner commented, "Some day, some smart inventor will come up with a watch with hands on it to take care of all these problems." — *D.M.*

Digging with Technology

To many people an archaeologist is a fusty old gaffer, scrambling about with his shovel in old tombs, in imminent danger of strangulation at the hands of a mummy inching ominously toward him.

A mummy craving an archaeologist today would have to step around the cesium magnetometer, plough through a pile of satellite photographs, and probably trip over the instruction manual explaining the latest piece of archaeological hardware.

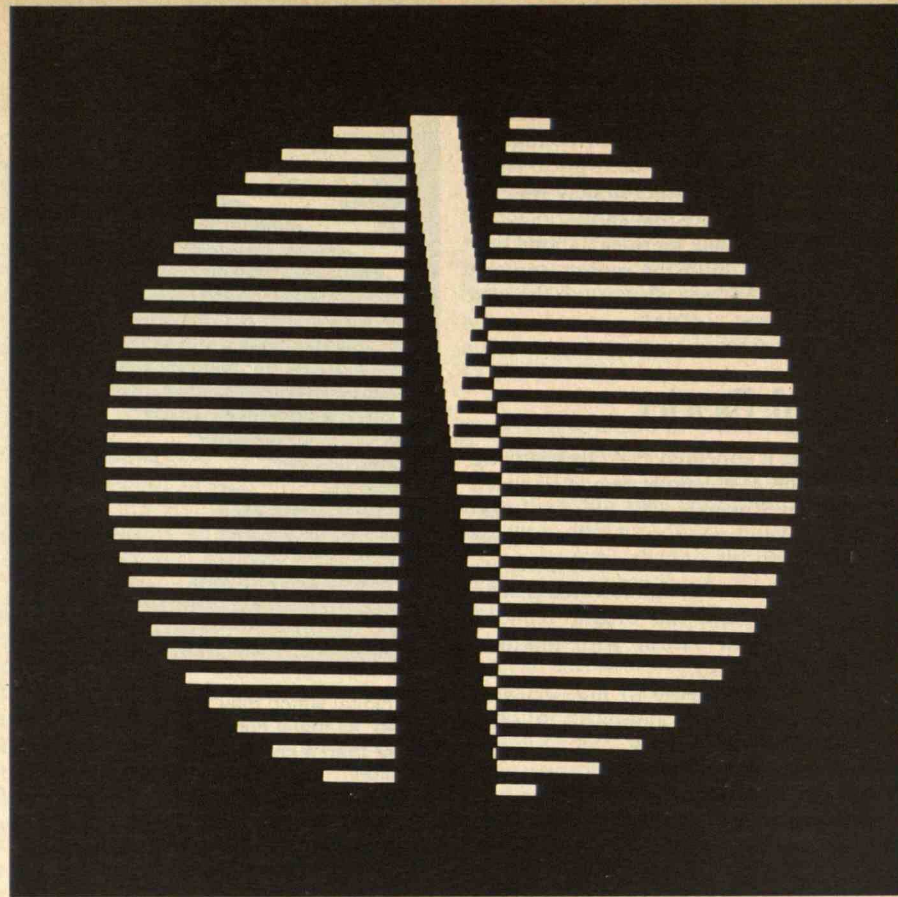
Archaeology has benefited from a host of scientific techniques for surveying archaeological sites and analyzing the materials found there, according to Froelich G. Rainey, Director of the University of Pennsylvania's Museum of Applied Science Center for Archaeology. In the September, 1976, *IEEE Spectrum* Dr. Rainey described some of the new tools. One important class of new devices is sensitive magnetometers that can detect fluctuations in the earth's magnetic field caused by masses buried up to six meters deep. The so-called "proton magnetometers" depend on the interraction between a "gyromagnetic substance" in the detector and the earth's magnetic field.

Dr. Rainey described one successful use of a "proton magnetometer" to search for the old Greek city of Sybaris, in southern Italy. For more than a century, archaeologists have searched for the city, now buried deep beneath silt washed down from surrounding mountains.

Dr. Rainey and his colleagues learned that they could detect buried walls by the minute differences in the earth's magnetic field they produce. The archaeologists would pass the magnetometer over the wall at right angles, plotting the magnetic anomalies to trace the wall's path. After eight years of plotting and excavating numerous structures in the area, the archeologists found large building foundations from the Sybaris period, but no real indication of the city itself.

"But for this writer, the flash of recognition came one evening in 1968 when I assembled the whole set of magnetic contour maps," said Dr. Rainey. "Suddenly I could see the precise location of the ancient Sybaris. . . . The series of maps indicated one specific area that was magnetically 'noisy' whereas all the rest of the plain was magnetically 'quiet.' " The final success came with the development of a "cesium magnetometer," which could see to a depth of 6 meters, as opposed to the 3.5 meter depths possible with the earlier proton magnetometer.

New techniques for dating artifacts have improved upon the long-used method of carbon-14 dating, said Dr. Rainey. One new dating technique Dr. Rainey and his colleagues are developing is a thermoluminescence method, which can determine the time at which a piece of pottery was fired. Thermoluminescence is the emission of stored energy, in the form of light, by a solid-state monconductor upon heating. When an artifact such as a clay pot is first fired, the high temperatures drive out all its stored energy, which is ever-so-slowly restored over millenia. Thus, when a ceramic sample from an archaeological dig is heated in the proper apparatus, the stored light energy given off can be measured and used to date the time the object was fired.



Computers may soon become standard household equipment, and computer-produced art such as this will be only one of their uses. A number of practical applications could spur "a consumer computer revolution," says one market analysis.

Another new method of dating involves measuring the extent of fission tracks from decaying uranium in an artifact. And still another dating technique, potassium-argon dating, used mainly by geologists, involves measuring the accumulation of argon-40, a product of the radioactive decay of potassium-40.

These new techniques are only a few of the archaeologists tools. Others include side-scan sonar which has allowed surveying of large areas of ocean for sunken artifacts. Satellite and aerial photography are just beginning to give archaeologists a bird's-eye view of settlements and migration patterns. Techniques for probing the earth with radar are being tested. It is ironical that the further technology advances into the future, the more clearly archaeologists will read the past. — *D.M.*

Fireside Computers

In the movie *The Graduate,* a family friend called the young hero aside and portentously whispered the word "plastics" into his ear as a bit of advice for his future. The same scene played today might well feature the phrase "hobby computers."

As computer costs plummet, marketing experts discern the beginnings of an explosion in the use of hobby computers in the home. A Massachusetts firm, Venture Development Corp., which claims to have completed the first comprehensive analysis of the field, predicts a market that could more than double each year, at least in the short term. The research firm identified more than 100 computer clubs, serving some 20,000 hobbyists, and concluded that the computer hobby field "promises to be nothing less than the leading edge of a consumer computer revolution."

Numerous computer hobby stores are already popping up around the nation, primarily in areas densely populated by professional computer users. In California are the Byte Shops, which plan nationwide franchising soon. In Massachusetts are the Computer Store in Burlington and the Computer Warehouse Store in Boston. All sell computer components, kits, and booklets for everyone from novice to expert.

Most computer hobbyists have in common their exposure to computers on the job. However, there are great differences in the interests the home computers serve. While some hobbyists build computers from scratch, or from kits, others would rather doodle around with pre-assembled systems.

The most common uses for the home computer include sophisticated game-playing, budget- and record-keeping, and computer-produced music, art, and even poetry. The computer games include tests of mathematical and logical skills and complex space-war contests, in which users pilot their craft through solar systems replete with space warps, gravity fields, and enemy space ships. Record-keeping functions range from simple check balancing and receipt storage to tax preparation and complex programs to guide the hobbyist in his everyday decisions. For instance, one hobbyist, having discerned a pattern in weekly supermarket specials, developed a program that lets his wife determine what days of the week to shop for what foods. This same hobbyist must meet a complex schedule of payments for his children's college tuition and utility, food, insurance, and housing bills. So he has programmed the computer to decide the optimum period, in terms of cash flow, for his annual vacation. He also feeds his daily dietary intake into the computer, which helps him maintain a low-salt, low-calorie diet by reporting when he has reached his limits.

Other hobbyists are developing computer controls for various mechanical systems in the home: for example, a computer-controlled lawn sprinkler system which monitors sensors embedded in the lawn and activates itself when the lawn needs watering.

Many computer hobbyists predict that the heyday of the home computer will begin with the introduction of the videodisc player, a machine which can play video records into a television set in much the same way that a phonograph plays audio records. Two videodisc systems to be introduced next winter by M.C.A.-Philips and RCA Corp. *(see*

October/November, 1975, p. 11) will soon allow programmed random access to any part of a videodisc program. Hooked to a computer, videodisc players could supply huge information banks. Stored data could include reference works, phone directories, how-to information, and computer programs.

One application of computer-videodisc systems would be teaching programs. A student would proceed through a videodisc program, responding to questions from the computer. According to his answers, the computer could direct the videodisc machine to replay information, branch into new areas, or continue with the same subject. Another tantalizing possibility would be fantasy videodisc adventures, in which the computer user could direct the course of the adventure by selecting various alternatives as the action proceeds.

The general consensus of those involved in hobby computers seems to be that the hobby computer represents a vast untapped market, ripe for exploitation. In fact, there are rumors that a major computer company is preparing to link with a major U.S. retail chain to market a computer kit for the home.

The key drawback to the field seems to be the lack of popularized public information as to the possibilities. Few people realize they can buy a fairly sophisticated system for about the cost of a set of good stereo components. More important, few realize that the computer could be helpful in their everyday lives, as well as a remarkably versatile source of amusement. And finally, although schoolchildren and professionals are learning computer languages in the school, office, and laboratory, the general public has not yet been shown that computer programming is not arcane magic, but a succession of logical, easy-to-formulate instructions.

Most computer hobby magazines today are hardware-oriented, perhaps intimidating the uninitiated. And they tend to emphasize game-playing, rather than the kinds of pragmatic programs that could draw the average person into a fascinating hobby. The computer companies have done little to interest the general public in the home uses of their product. They would all do well to realize that they are not in the computer business, but in the information business. — *D.M.*

PUBLIC HEALTH

The Ames Test: Pass-Fail for Chemicals

"It's no longer surprising to open a newspaper and find that another carcinogen has been discovered," says University of California biochemist Bruce Ames. He should know, for his laboratory has implicated many chemicals as possible carcinogens. Tests by Dr. Ames and his colleagues on hydrogen-peroxide hair dyes and on a fire retardant commonly applied to children's pajamas were both widely reported this year. The National Cancer Institute is doing extensive and detailed animal carcinogenicity tests on some of these substances as a result.

The detailed animal test programs will cost more than $160,000 apiece to run, and the tests take at least two years. In sharp contrast, the test used by Dr. Ames took only two days and cost only a few hundred dollars.

The test, developed by Dr. Ames over the last ten years, is one of the first rapid tests for cancer-causing ability in chemicals. A researcher performing the Ames test puts the chemical to be tested on a petri dish containing a medium that supports a form of *Salmonella* bacteria. The bacteria is a mutant strain which cannot reproduce, because of an inability to produce histidine, an amino acid necessary for growth. After 48 hours of incubation, the researcher counts the number of bacterial colonies growing on the dish. These show up easily as round, fuzzy areas. The more colonies of bacteria, the more mutations the chemical has caused.

Basic theory holds that mutations represent damage to the DNA in the cells' genetic material. Many believe that cancer can result from mutation. "The oldest theory of cancer is that DNA mutates to become a tumor cell," says Dr. Ames.

The Stanford Research Institute, one of the first places to perform in-depth tests on the efficiency of Dr. Ames' test, found that 75 per cent of the 200-odd known carcinogens also showed positive results on the Ames test. Since that study two years ago, Ames and his colleagues, particularly Dr. Joyce McCann, have improved the test and have shown that it detects 90 per cent of 175 carcinogens tested as mutagens and very few non-carcinogens.

One crucial aspect of the Ames test is that an extract of liver is added to the petri dish before it is incubated. The addition of liver homogenate, according to Dr. Ames, makes the test a closer analog to the way mammalian metabolism handles carcinogens. Many times a mammal's body, in its attempt to transform ingested chemicals into excretable products, creates a harmful substance from an innocuous one. The liver homogenate, says Dr. Ames, metabolizes chemicals much as would a live mammal.

Mutagenicity is not carcinogenicity, however, and some scientists have been quick to point this out. Molecular biologist Harry Rubin, also at Berkeley, strongly objects to the use of mutagenicity to indicate cancer-causing ability. In fact, he said in a letter in the January 23 issue of *Science,* while he sees no harm in using the test to screen for mutagens, to use the test to screen for carcinogenicity is "a bit like looking under the lamppost for the coin lost a block away because of the availability of light." Other scientists point out the wide difference between complicated human genetic material and the simple bacterial genetic material.

Vince Simmon, who oversees research in microbial genetics at the Stanford Research Institute, is convinced that the correlation between a chemical's tendency to cause mutations and cancer is more than fortuitous. "Arguments can be made that there is no correlation, but evidence is strong that chemicals that react with DNA and cause mutations also cause cancer," he says. He cites experimental evidence showing that DNA irreparably damaged by certain chemicals can cause a cell to behave erratically, and possibly become cancerous.

Researchers at S.R.I. routinely test chemicals for carcinogenicity using the Ames test. Over the past three years they have performed tests for over 25 industrial clients, as well as for the Environmental Protection Agency and the National Cancer Institute. If a compound tests positive, it has a very good chance of being carcinogenic, and the client is notified of the results. If the compound tests negative, the makeup of the chemical is noted. "The test doesn't work at all for some compounds," says Dr. Simmon. The spectrum of polyhalogenated hydrocarbons — including dieldrin, aldrin, and kepone — show no evidence of mutagenicity on the test.

In the last year and a half, 150 industrial labs have also begun using the test. At a laboratory that performs toxicology and industrial medicine for Du Pont the test is used to determine which of several potential chemical products seems safest, and what industrial processes require development of stronger safety procedures. The results of the Ames test are a big help in "designing out carcinogenicity from the beginning," according to Burroughs Wellcome researcher Don Clive. If nothing shows up on the Ames test, the chemical is deemed a good bet for the next step — the expensive animal test. Time and money is saved this way, he says.

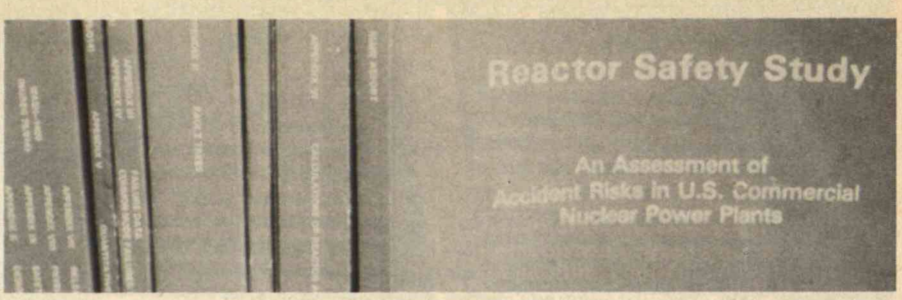
The positive response from industry is what Dr. Ames has been looking for. A long-time advocate of pre-testing industrial chemicals, he terms suicidal the practice of producing millions of pounds of a chemical before thorough investigations of its possible effects. Tests of chemicals "in the pipeline," before large-scale production and while other options are still open, is the answer.

Fine-tuning on the Ames test is not yet complete. Better data on the applicability of bacteria tests to human experience is needed, says Dr. Ames. He is now working on methods to determine the potency of a chemical's carcinogenic abilities, and the correlation of this with mutagenic potency. — *S.J.N.*

Rasmussen Report Revisited

The epic study of nuclear power plant safety known as the "Rasmussen Report" has once more become the focus of controversy. A new analysis charges that the report is so riddled with uncertainties as to be an inadequate policy tool.

According to a study by Joel Yellin, Associate Professor of Social Sciences at M.I.T., the Rasmussen report does not enable planners to choose wisely among various energy technologies or to make specific plant siting decisions. However, Dr. Yellin's analysis has drawn comment from Dr. Rasmussen and other experts, which, in turn, cast doubt on Dr. Yellin's critique.



The many-volumed Reactor Safety Study, WASH-1400, nicknamed the "Rasmussen Report" after its director, Norman C. Rasmussen, is once again the object of controversy. A recent analysis sponsored in part by the Ford Foundation takes issue with the study's optimistic assessment of the likelihood of catastrophe as the result of nuclear accident at a U.S. nuclear power plant. (Photo: Susanne Fairclough)

The $3-million Reactor Safety Study, WASH-1400, was nicknamed the "Rasmussen Report" after its director, Norman C. Rasmussen, head of M.I.T.'s Department of Nuclear Engineering. Issued in its final version in October, 1975, the report concludes that the likelihood of a catastrophic nuclear accident at a U.S. nuclear power plant is far lower than the likelihood of catastrophes from many industrial processes or natural disasters (*see October/November, 1974, p. 14*).

Dr. Yellin's critique of the report does not argue that nuclear plants are safe or unsafe, and he makes no claim that major accidents are likely. But the WASH-1400's assessments are judged unreliable because of the many uncertainties in calculating the likelihood to accidents, and the report's failure to account for long-term fatalities from a nuclear accident in comparing nuclear and non-nuclear risks. The critique was published in the Spring, 1976, issue of the *Bell Journal of Economics*. Dr. Yellin performed the study as part of a long-term project on the political and economic ramifications of nuclear power, sponsored in part by the Ford Foundation.

Long-Term Latent Health Risks?

Dr. Yellin observes that the Rasmussen study compares the risks of immediate fatalities from a nuclear accident with immediate fatalities from non-nuclear accidents, such as fires, explosions, dam failures, air travel catastrophes, toxic chemicals, tornados, hurricanes, and earthquakes.

However, Dr. Yellin notes, WASH-1400's authors estimated that, on the average, every prompt fatality from a nuclear accident is expected to be accompanied by about 670 latent cancer fatalities, spread over a period of 10 to 40 years. The Rasmussen report stated that it did not include these long-term effects in its comparative calculations because similar long-term data were not available on the risks from non-nuclear activities.

"Considerable partial information is, in fact, available regarding industry-related health risks, in particular risks due to chemical carcinogens," said Dr. Yellin. "That information should have been used in the WASH-1400 risk comparisons."

Dr. Yellin conducted a limited sampling of public health risks due to industrially produced substances, and found that unlike the large gap between the *immediate* dangers of nuclear versus non-nuclear catastrophes — presented in WASH-1400 — there was no evidence of a large gap between nuclear and all other non-nuclear long-term *latent* health risks. Dr. Yellin also pointed out that, since U.S. energy policy emphasizes coal-fired power plants as the other major energy source besides nuclear power, information on coal-related health risks would have lent relevance to WASH-1400, and should also have been included.

Harvard physicist Richard Wilson, in a rebuttal to Dr. Yellin (published in the fall, 1976, issue of *Bell Journal*) contends that there *are* studies where the roles of the complete coal fuel cycle are assessed. A comparison of this data with the WASH-1400 data shows that a large gap does exist between coal and nuclear health risks, with nuclear proving much safer.

However, scientists familiar with the WASH-1400 report, including Dr. Rasmussen, have pointed out that there are considerable difficulties in combining measures of immediate fatalities with measures of latent fatalities. Estimates of immediate deaths from a plant accident are fairly straightforward and easily obtainable. But latent fatalities from a nuclear accident are very much creatures of the world of statistics, and these very tenuous measures are easily lost in the general "noise" of health statistics.

As to WASH-1400's failure to include health risks from other energy sources, Dr. Rasmussen notes that WASH-1400 was not meant as a comparative vehicle for energy-related risks, and that Congress specifically restricted the study's scope to include only nuclear risks.

The Rasmussen report is also inapplicable to problems of nuclear plant siting, Dr. Yellin argues. First, the report does not discuss the particular characteristics of sites near large metropolitan areas, but combines all the sites expected by 1981 into a single assessment of individual reactor risk, based on a weighted averaging procedure. The possibility that sites near urban areas may produce much greater fatalities than sites in lightly populated areas is obscured, he said. Such an amalgamation of data may negatively prejudice a siting decision concerning a plant in a lightly populated area and prevent planners from making a fair assessment of the dangers of siting a power plant in a heavily populated area. Individual power plant sites also differ in other specific characteristics, such as weather patterns, which may affect the overall risk assessment, says Dr. Yellin.

Dr. Wilson concurs with this criticism but contends that it is overstated. It is possible to make site comparisons using the WASH-1400 techniques, but he points out that in any case, WASH-1400 will almost certainly not be used as a major basis for site selection.

How Rare Are "Rare" Failures?

Dr. Yellin also criticizes the "fault-tree analysis" used in WASH-1400. To analyze the likelihood of accidents, WASH-1400 considers only the dominant modes of failure, neglecting modes of failure which have not yet observably affected the reliability of reactors or of individual components.

However, Dr. Yellin argues, these "rare" modes of failure could loom larger as reactor experience mounts; each reactor or plant site may have individual peculiarities not previously observed. As proof of the possible importance of unusual occurrence, Dr. Yellin cites the fire in the cable room of the Browns Ferry, Ala., nuclear plant. The fire started when a technician, searching the area with a

candle, ignited cable insulation.

According to Dr. Wilson, Dr. Yellin is only partially correct in this criticism. Any significantly dangerous modes of failure would have included failures of components that would have already been readily apparent. However, he said, there should be a search for such undetected modes of failure, although the risk is low that they actually exist.

Dr. Yellin also took issue with some basic techniques of the analytical method of "fault-tree analysis" used in the reports. Subjective judgments were made on the vulnerability of particular power plant components to failure, and the effects of component aging are not treated. According to its authors WASH-1400 ignores aging considerations because the study was not meant to be extrapolated beyond 1981. Dr. Yellin emphasized that this approach still leaves open the important question of the long-term safety of nuclear plants.

WASH-1400 includes calculations regarding possible failure-causing interactions of the interdependent components of a nuclear power plant. "Such effects are central to any discussion of possible uncertainties in the numerical results of the fault-tree analysis," said Dr. Yellin. However, the report makes a very weak case for the validity of the assumptions underlying the analysis, he charged. Dr. Wilson concurs with this assessment, pointing out that the mathematics used for estimating some common-mode failures was quite unclear. However, he said, in all common failures of importance, the numbers were, in fact, taken from other, more direct evidence.

Because of such defects in computational procedures, the Rasmussen report's estimate of one major reactor accident in one billion years of reactor operation may be in error, according to Dr. Yellin, by an overall factor of one hundred thousand to one million. The Nuclear Regulatory Commission has by no means ignored such criticisms, Dr. Yellin pointed out, and they plan to address them in future studies.

Overall, Dr. Wilson found Dr. Yellin's criticism of WASH-1400 "mostly overstated"; although some criticisms are valid, they are maily criticisms of presentation.

Despite the criticisms by Dr. Yellin and others, the WASH-1400 report still stands as an important and generally valid study. The analysis of health risks from energy production has undoubtedly moved far beyond the narrow scope of the report, but the report still represents a firm base upon which to build. — *D.M.*

Oil Industry: Old Before Its Time?

Originally there were 442 billion barrels of crude oil under the U.S. and its offshore continental shelves. One quarter of that has now been produced, and another 32.7 billion barrels are considered "proved reserves," ready to use.

But 300 billion barrels of oil remain classified as "unrecoverable." How much of that vast resource we can eventually bring out of the ground depends on the state of technology and the price we are willing to pay. In the meantime, despite this vast unproduced resource, the U.S. petroleum industry characterizes itself as "on the decline," and funding and staffing are growing problems for the handful of schools that teach petroleum engineering.

These apparent inconsistencies appeared in papers prepared for A.I.M.E.'s Society of Petroleum Engineers in New Orleans last fall, where they shared the program with a number of highly technical presentations that signified continuing U.S. leadership in one of the most technically demanding industries.

Only economics stand between us and at least half of those 300 billion barrels of "unrecoverable" oil, said John J. Simpson, an oil economist for Citibank. Already, technology for enhancing oil recovery has raised the yield from about 15 per cent in the 1930s to today's 30 per cent; and Mr. Simpson quoted experts who say that "rising demand, improved technology, and economic incentives [could] spur recovery to the 60-to-65-per-cent level."

Meanwhile, Wayne E. Glenn, Vice Chairman of Continental Oil Co., proposed that the U.S. petroleum industry, pressed by competition from foreign producers who are still pumping the inexpensive oil that is easiest to extract from newly-tapped pools, is on the decline — or about to be. In the past decade the ground rules governing the industry in this country have changed: instead of owning and exploiting worldwide resources, U.S. companies are now contractors who fund and develop others' resources — and who, at the same time, are asked to train foreign nationals who will in time displace their teachers.

For the present, petroleum engineers are in keen demand. Graduates in this field command \$50 to \$100 per month more than other engineering graduates every June in the Southwest, said Mr. Glenn. Petroleum engineering faculties are being depleted because the budget-conscious university cannot compete with such high salaries, said Professor Kermit Brown of the University of Tulsa.

Put together, all these arguments seem to urge new incentives which the market system is not now providing the petroleum industry. Despite its complaints about the burdens of government interference in its business, the industry would welcome more support for education and research in petroleum engineering, and technical and economic incentives to tap the 60 per cent of the oil that is now left behind in every pool it pumps. — *J.M.*

When Stuart Symington joined the U.S. Senate in 1952, he was told by a colleague that the subject of nuclear energy was "so secret I do not want to know anything about it." The same attitude prevails today, Senator Symington told a Harvard Arms Control Seminar late last fall — one reason why both national and international nuclear control policy is an "incredible mess," he said. (Photo: Rick Stafford for *Harvard Gazette*).

The "Nuclear Mess"

On the eve of his retirement after a 25-year career in the U.S. Senate, Stuart Symington finds the nation and the world in a dangerous "nuclear mess. . . . Control over nuclear energy is slipping at both the national and international levels," he told the Arms Control Seminar of Harvard University's Program for Science and International Affairs late last fall.

On the international level, said Senator Symington, "a system of inspection, and a faulty one at that, is superimposed upon an otherwise uncontrolled exploitation of nuclear energy by a rapidly growing number of countries." Senator Symington's solution: we must "put 'teeth' in the institutions we have." This would include:

— strengthening the non-proliferation treaty;

— encouraging non-members to join in that agreement;

— increasing and broadening the capabilities of the International Atomic Energy Agency; and

— joining with other nuclear powers "to establish meaningful restrictions on the present uncontrolled commerce in nuclear materials."

On the national level, Senator Symington worries about secrecy and "the pervasive disorganization of authority." In the executive branch 21 agencies and councils share decision-making in nuclear matters, and at least 19 congressional committees divide and oversee nuclear matters. As a result there exists "no true coordination and a good deal of competition"; there is "growing diffusion of authority and responsibility in this field." He wants secrecy ended and the decision-making process streamlined. — *J.M.*

Each year, 200 million tires are discarded. So far, these worn-out tires have resisted recycling. But as energy and raw materials become less abundant, industry is finding that old tires have good uses. (Photo: F.S. Lincoln)

How to Reclaim 200 Million Tires

Even discarded automobile tires are yielding to pressure from the rising prices of energy and raw materials. There are 200 million a year in the U.S., and they are one of our most intractable forms of trash.

Two routes to reclamation are proposed:

— A worn-out automobile tire can be burned to produce heat at the rate of 13,900 B.t.u.s per pound, the equivalent of about 2.5 gallons of fuel oil; 1.13 million tires a year are now being used in this way to produce process steam by the Goodyear Tire and Rubber Co. in Jackson, Mich.

— Decomposed chemically, a ground-up tire can be made to yield nearly 40 per cent of its weight in a combustible oil whose heating value is about 17,000 B.t.u.s per pound; 35 to 40 per cent of its weight in char which can be recycled as carbon black into new tires; and 15 to 20 per cent of its weight in gaseous light hydrocarbons — heating value about 2,100 B.t.u.s per cubic foot.

Goodyear feeds whole tires, at the rate of 130 (3,100 pounds) per hour, to a special rotary furnace. Steel beadwire in the tires is oxidized in the 2000°-F. heat, and a char consisting principally of carbon black remains behind. The designers of the system — F. Michael Lewis of Stanford Research Institute and Paul W. Chartrand of Lucas American Recyclers, Inc., who reported the project to the 1976 National Waste Processing Conference in Boston — believe that perhaps 5 per cent of the furnace's output will be required to power a sophisticated scrubber now being built to control pollutants.

Three engineers from Occidental Research Corp. — S. C. Che, W. D. Deslate, and K. Duraiswamy — reported on Occidental's "flash pyrolysis" process applied to tire-recycling at the 1976 Intersociety Conference on Environmental Systems. It's still at an early stage of development, with Occidental's evaluation based on a laboratory system. But that evaluation is promising: with tires at $15 per ton and allowing $25 per ton for grinding them into fiber-free, rock-salt-like particles, a plant processing 300 tires a day could produce $9.5 million in gross revenues per year (carbon black at 10 cents per pound and oil at 30 cents per gallon). Such a plant would pay for itself in less than six years, say the Occidental engineers. But they admit that the economics are "highly sensitive" to the costs of scrap tires and of grinding them, suggesting that radial tires with increasing amounts of steel may be Occidental's undoing. — *J.M.*

Engineers as Governors

Few top government positions are held by engineers — even in agencies whose work depends heavily on technology. There ought to be more, thinks Myron Tribus, Director of the Center for Advanced Engineering Study at M.I.T. — not so much because of their expertise as because of their style of working.

Lawyers made the adversary proceeding the dominant process of government today, Dr. Tribus told the American Society of Mechanical Engineers last winter. Lawyers are by far in the majority of high-ranked government posts, and the formalized adversary process is a basic contribution to government of which the legal profession has a right to be proud.

But the adversary process has limits. "Legal processes are designed mostly to deal with what already exists or with plans already conceived," said Dr. Tribus; they "do not encourage creativity."

The process of engineering is very different, concerned with manpower, materials, machines, money, schedules, skills, trade-offs, and risks. "In technical work it is absolutely essential that the processes of discussion be so structured that information from the lowest levels can safely be transmitted upwards. . . . If the environment discourages free discussion and debate, if it discourages commentary counter to the wishes of the majority, then critical information will not percolate to the top," said Dr. Tribus.

Engineers should not be content with the role of advisers, ready to bring forward their facts and conclusions when asked. "In politics the name of the game is power. If technical people are not present and with power to influence the way the game is played, the political process will simply destroy the technological process." — *J.M.*

The Fudge Factor

Cheating scandals rock some of the most prestigious academic institutions, and news magazines headline the questionable academic ethics of today's youth. If the students are so flush with moral turpitude, one wonders what their professors are up to. Or, more important, how common is cheating among scientists in general?

Dr. Ian St. James-Roberts, a lecturer at the University of London, became one of the rare souls to ponder the question publicly in the September 2, 1976, issue of *New Scientist*. He declares that "double-blind procedures and control groups are part of the substantial array of techniques science has for coping with unintentional bias. Yet science seems to ignore another source of error: intentional bias — the

purposeful manipulation of an experimental design or results to confirm an hypothesis."

Quantifying intentional cheating in the laboratory is almost impossible, says Dr. St. James-Roberts, for only the investigator is certain of his intentions. Only he knows whether data were mishandled by accident or on purpose. And, of course, there are infractions of honesty so small as to be amusing, rather than dangerous (*see box*).

Predictably, cheaters have been exposed only seldom in science, rather an odd circumstance considering that scientists are subject to the same human frailties as everybody else.

Dr. St. James-Roberts cites the affair of the N-rays as an example of how spurious results can sidetrack science. In 1903, French scientist René Blandot claimed to have discovered a variant on X-rays — N-rays — which could travel through metals and other materials that block X-rays. In the two years before the research was exposed, dozens of laboratories reported detection of the rays. The rays emanated from muscles, nerves, and the brain, had a spectrum, and were transmittable by wire, many scientists claimed. The French Academy even bestowed an award on Blandot for his work. The false claims were exposed when another professor showed that the rays were due only to the imagination of the experimenters.

A more recent example of dishonesty is the 1974 case of Dr. William Summerlin of Sloan-Kettering Institute. Dr. Summerlin admitted he painted laboratory mice to make them appear as if they had received successful skin grafts. Such a grafting would have marked a breakthrough in overcoming the immunological barrier that causes transplant rejection.

Controls to prevent prevarication are needed, argues Dr. St. James-Roberts, so that unexpected results, and in fact entire areas of inquiry, will not be dismissed because of the possibility of intentional bias.

The current principal safeguard against scientific fakery, of course, is the requirement that experimental results be independently replicated before being accepted. However, argues Dr. St. James-Roberts, this safeguard works poorly: many small corners of science are supported by only a few investigators; and scientific journals dislike repetitive material from these special areas. Further, in even more sophisticated research, few investigators may have the competence to replicate some experiments.

Despite scientists' dedication to the ideal of truth, powerful pressures can be exerted by months of negative results, a publish-or-perish dictum, and ambition.

Journals, the scriptures of scientific belief, are often loath to accept negative findings. Dr. St. James-Roberts knows; he conducted experiments to see whether student researchers would manipulate results when given the chance, and discovered they wouldn't. The results were denied publication specifically because they were negative.

Although investigation of faked results will be unpleasant, Dr. St. James-Roberts feels it is science's duty to forge ahead: "At the least such an unskeptical attitude is a curious one for a community whose way of life is based on skepticism." — *D.M.*

What They Really Mean

The research report is certainly one of the most amazing of journalistic worlds — where all the data are precise, they are obtained correctly the first time, and the investigator is blessed with instant insight.

But for those who want to read between the lines, here is a brief glossary of the true meaning of various report phrases, adapted from an article by C. D. Graham, Jr., in a 1957 issue of *Metal Progress*. (We found it in *A Random Walk in Science* by R. L. Weber, New York: Crane, Russak & Co., Inc., 1973.)

When Scientists Write:	*They Really Mean:*
It has long been known that . . .	I haven't bothered to look up the original reference.
While it has not been possible to provide definite answers to these questions . . .	The experiments didn't work out, but I figured I could at least get a publication out of it.
High-purity . . . Very high purity . . . Extremely high purity . . . Super-purity . . . Spectroscopically pure . . .	Composition unknown except for the exaggerated claims of the supplier.
Three of the samples were chosen for detailed study . . .	The results on the others didn't make sense and were ignored.
. . . accidentally strained during mounting	. . . dropped on the floor
. . . handled with extreme care throughout the experiments	. . . not dropped on the floor
Typical results are shown . . .	The best results are shown.
Although some detail has been lost in reproduction, it is clear from the original micrograph that . . .	It is impossible to tell from the micrograph.
Presumably at longer times . . .	I didn't take time to find out.
It is suggested that . . . It is believed that . . . It may be that . . .	I think.
It is generally believed that . . .	A couple of other guys think so too.
It might be argued that . . .	I have such a good answer to this objection that I shall now raise it.
It is clear that much additional work will be required before a complete understanding . . .	I don't understand it.
Unfortunately, a quantitative theory to account for these effects has not been formulated . . .	Neither does anybody else.
Correct within an order of magnitude . . .	Wrong.
It is to be hoped that this work will stimulate further work in the field . . .	This paper isn't very good, but neither are any of the others in this miserable subject.

The optimist emphasizes that wind energy is free, inexhaustible, and nonpolluting. The skeptic recounts the difficulties and uncertainties of collecting and converting it. The author places himself among the cautious optimists

Say "windmill," and most people think of either or both of these landmarks of the Dutch farmlands (left) and the American midwest. Both are horizontal-axis machines. By 1850 some 9,000 windmills were working in the Netherlands, pumping water and grinding grain; some were immense, with "sails" 30 feet long and rotors 80 feet in diameter, generating 30 to 40 h.p. in winds of 25 m.p.h.; this calculates to 7 per cent efficiency. The multivane fan (right), invented in the U.S. in the 1850s, was universally used for lifting water — often to much greater lifts than the Dutch-type windmills. The social impact of this machine in terms of opening the western lands to agriculture and rail transportation was very large. (Photos: Harold M. Lambert, Ewing Galloway)

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Wind Energy for Human Needs

Systems to draw power from the wind have served man during at least 2,000 years of human history. However, the discovery and exploitation of coal, oil, and gas on an increasing scale in recent centuries has relegated wind power to an ever-smaller role. Interest waxed briefly in the 1920s and 1930s, when the technologies of fossil fuel extraction and electric generation were still young and when the technology of wind-powered electric generation had not been fully explored. Now the economic, environmental, and geopolitical problems of a fossil-fuel- or plutonium-based world energy structure are once more bringing a resurgence of interest in wind energy. Emotion and romance aside, can the power of the wind in fact be harnessed on a practical scale to provide substantial amounts of energy to an industrial society such as ours, at a lower economic and environmental cost than fossil or nuclear alternatives?

Windmills of History

The exact date of the invention of the windmill is uncertain, but vertical-axis machines have been capturing the energy in Persian winds since the first millenium A.D. These windmills, with windcatching surfaces as much as 16 feet long and 30 feet high, were devised for grinding grain. Machines of this type are used today in eastern Persia (Iran); they appear to be similar in many respects to their ancient counterparts.

The western world discovered the windmill much later; the earliest written references to working windmills are 1105 A.D. (Arles, France), 1180 A.D. (Normandy) and 1191 A.D. (England). From that time the use of wind energy developed continuously in England, the Netherlands, North Germany, Denmark, and elsewhere. According to E. W. Golding, there were at one time over 10,000 windmills grinding corn and pumping water in Great Britain. These were the familiar "Dutch" windmills — horizontal-axis, sail-type machines. Some had large rotors, 60 to 80 feet in diameter, with power outputs of 30 to 40 horsepower in winds of 25 m.p.h. (If a windmill sweeping an area 80 feet in diameter can produce 40 horsepower, it has captured about 7 per cent of the energy in a 25-m.p.h. wind.) Although these very large machines were numerous, most windmills were smaller. The Dutch reclaimed much of their land from the sea using two-horsepower windmills.

A great virtue of the "Dutch" design was that the windmills could be built locally even in large sizes, without factory technology or high-performance materials. Many were built without metal, for example.

The Dutch-type windmill is obsolete today, hopelessly expensive to build and maintain. Two other major types of wind machines — the multivane fan and the thin-bladed propeller — have replaced it as the machines of widest use. These three major types account for well over 90 per cent of all stationary wind devices ever built. All are horizontal-axis devices, distinguished by the geometrical form of their wind catching surfaces.

The multivane fan — the familar "farm windmill" of the American Midwest and West — was invented in the United States in the second half of the 19th century and has spread throughout the world. It is still being produced and used, though in reduced numbers, and shows no sign of becoming obsolete. It is best suited for pumping groundwater in small quantities with moderate to large lifts. Without the multivane fan, beef production over large areas of the American West, the Australian interior, and elsewhere would not be possible, even today. Until dieselization, many transcontinental rail routes in the United States depended on large multivane fans to pump water for locomotives.

The moderate rotation speeds of the multivane fan simplify mechanical design and contribute to low maintenance and extreme longevity in the installed machine. Although wooden multivane fans could be built by hand — and were in the early years — the universal practice today is to build them of steel in a factory. The largest size manufactured (30 feet in diameter) gives an output of about four horsepower in a 15-m.p.h. wind, but fractional horsepower outputs are much more common. Many units installed over 50 years ago are still in active use, with minimal maintenance. This reliability is one of the multivane fan's most attractive features. The multivane fan is a static technology, and it will probably not see further improvement or broader application.

The third type of horizontal-axis wind machine is the propeller with two or three thin blades rotating at high speed. Such propellers have much higher aerodynamic efficiency than fans with wide blades, and they use materials more efficiently. The high aerodynamic efficiency is only present at high blade speeds, which means that rotational speeds are also high, especially in smaller units. Indeed, propeller type windmills are sometimes known as the "high-speed type."

High rotational speeds are very appropriate for driving electrical generators, and until very recently all wind-powered electric generators were of this type. Small propellers which swept circles four to six feet diameter were produced in quantities of hundreds of thousands in the

U.S. in the 1930s and 1940s to provide electricity to farms beyond the reach of central-station power. These small wind generators, producing a few hundred watts of power, supplied only a fraction of farm or household energy needs. Typically they were used to charge lead-acid storage batteries to operate radio receivers (which required more power in pre-transistor days), while the rest of the energy used on the farm was supplied by oil, gas, wood, or animals. The extension of the central power grid to virtually every household in the United States by the early 1950s eliminated the mass market for small wind generators. The propeller-type wind turbine has survived, as a commercially available energy source, for application in remote locations where electricity is needed and central-station power is not available.

Radios came to the midwest in the 1930s, often long before central-station electric power, thanks to wind machines such as this. The wood blade is six feet long, and the machine's rated output in a 20-m.p.h. wind is 200 watts at 12 volts d.c. — ample for a radio receiver but hardly for a homestead. The 1974 price — the machines are still in production — was $500.

A Large but Frustrating Energy Resource

The amount of energy in the ocean of moving air above the earth's surface is enormous — and irrelevant. The technological problem of extracting any part of it at any reasonable cost is substantial. The density of air is not great, so equipment to remove appreciable amounts of energy from moving air must necessarily intercept a large area. The size of the equipment limits the practicality of wind-energy schemes. Unlike water, the air stream cannot be easily concentrated by channelizing, cannot be held back to store energy, cannot even be seen, and constantly changes direction and speed.

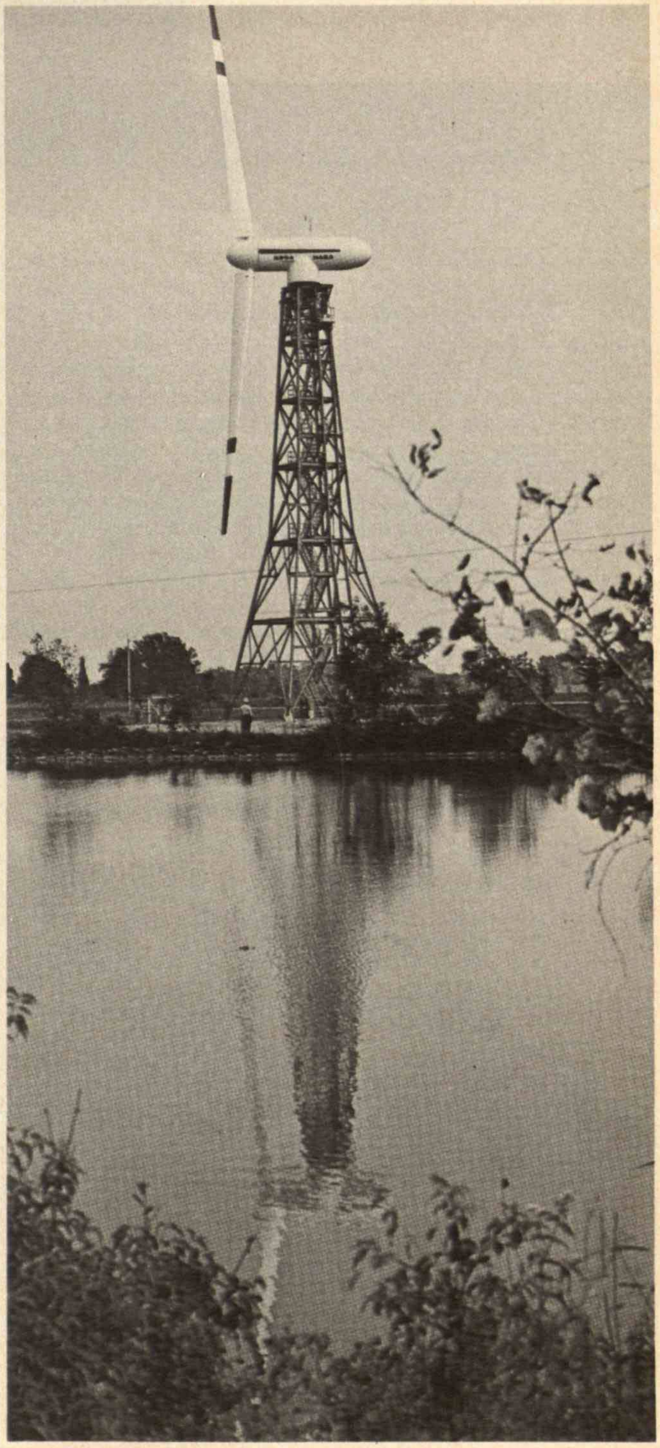
The present state of knowledge of the magnitude of the wind energy resource is very unsatisfactory. Most wind measurements are made at airports, close to the ground; they have only limited relevance to wind-energy programs. Local topography influences the wind greatly, so that regional wind surveys, though useful, have only the sort of relevance that geological survey mapping has to finding minerals. Winds vary considerably from year to year; in Amarillo, Texas, for example, the total energy in the wind was 1,652, 2,290, and 1,852 kilowatt-hours per square meter per year in 1970, 1971, and 1972. This is a difference of 30 per cent between annual totals from one year to the next. Monthly variations between years (February, 1970, compared with February, 1971, for example) were often even more.

Wind contour maps of large regions, though interesting, are not enough for wind energy engineering. Although it is generally true that strong winds predominate in the temperate and polar regions and weak winds in the tropics; that winds are stronger in oceanic and coastal areas than inland over continents; and that winds blow harder in mountain highlands than on plains, large variations often invalidate general patterns. For example, the long-term average windspeed at Honolulu airport is 11.2 m.p.h. About ten miles away in a mountain pass (Pali Lookout), the average wind is much higher, probably over 30 m.p.h. Consider the monthly averages of measured night windspeed at the summit of Mauna Kea, Hawaii (13,796 ft. elevation, the highest point by far for thousands of miles in any direction): three of the 12 are over 18 m.p.h., one is over 21 m.p.h., and four are under 14 m.p.h. Though not small, these average windspeeds are much lower than would have been expected considering the unique nature of the site.

While the plains of the North American midcontinent are quite windy, the plains of North India are not windy at all. A wind survey of all of India found no annual average windspeed higher than 11 m.p.h., compared with — for example — 14.6 m.p.h. reported for New York City. An English study reports 49 sites in the British Isles with average windspeeds of over 18 m.p.h. Average windspeeds (at airports) for 40 U.S. cities range from 6 to 15 m.p.h. One of the very best sites known anywhere is Mount Washington, N.H., where the U.S. Weather Bureau reports a long-term average windspeed of about 36 m.p.h. at the summit.

Within areas with high average windspeeds, preferred windpower sites can be found where the velocity is increased, sometimes substantially, because the wind is forced to flow around obstacles, through notches in ridgelines, etc. Variations of 20 per cent in windspeed, corresponding to a difference of 70 per cent in energy content of the wind, between sites separated by only a few tens of meters are common. For this reason, the

This 100-kilowatt wind generator near Sandusky, Ohio, is the largest wind machine now in operation anywhere in the world. It was built by N.A.S.A. as an experimental prototype at a cost of about $1 million, and it has revealed at least two problems with which designers of future installations must deal: stresses in the 62-foot blades have been greater than expected, and that problem has been compounded by vibrations attributed to erratic wind flow around the tower. N.A.S.A. and E.R.D.A. are now at a work on plans for a 1,500-kilowatt generator, and Richard L. Putoff, Program Manager of the N.A.S.A. wind power effort, says wind energy may ultimately provide up to 5 to 10 per cent of U.S. electricity demand.



search for the best wind sites is very much like prospecting for minerals: a geological survey map is essential, but the actual location of the deposit has to be pinpointed by detailed local search.

To evaluate a site for power production, a long interval of wind measurements (several years) is desirable. The power in the wind at any instant depends on the cube of the wind velocity, so the average value of the velocity cubed is the figure needed to assess the power in the wind, averaged over time. Often the average value of windspeed is quoted instead, but of course the cube of the average is not the same as the average of the cube, and there remains the question — not trivial — as to whether the average value of v^3 can be inferred from the average value of v. If the so-called "structure of the wind" were the same at all sites, then a measurement of average velocity, which is relatively easy to acquire, could be routinely converted into the required v^3 for all potential sites. Considering the large year-to-year and point-to-point fluctuations in average windspeed, however, the point may be of more interest than importance.

Some wind power advocates feel that the importance of selecting excellent sites has been overstated. According to this view, the detailed survey and site selection work is a labor-intensive, time-consuming, and expensive activity, and ultimately the economics of wind generation are such that site selection will not pay for itself if it is overdone. Mass production and installation of large numbers of wind machines are the key to wind energy economics, according to this view. If high towers are used good wind will usually be found, and even though each individual installation is not optimized the cost/benefit ratio for the whole windpower system will be better. This is not the prevailing view at present.

Physics and Technology of Wind Machines

The energy in the wind is the kinetic energy per unit volume of moving air, or

$$T = \frac{1}{2} \rho v^2,$$

where v is the velocity and ρ the density of air (typically 1,200 grams per cubic meter). The number of unit volumes arriving at a wind machine per unit of time is just equal to the windspeed (a 10-meter-per-second wind will deliver 10 cubic meters per second of air to a machine having a cross section of one square meter), so the power in the wind is

$$P = \frac{1}{2} \rho v^3$$

per unit area perpendicular to the wind direction.

No wind machine can extract 100 per cent of the power in the wind. (If this were possible, the velocity of the air downstream of the wind machine would be reduced to zero, and the air would pile up and accumulate!) For horizontal-axis machines there is a rigorous upper bound, called the Betz limit, to the fraction of the power in the wind which can be extracted; the fraction is 16/27, or 59.3 per cent. Real horizontal-axis machines of the two- or three-bladed propeller type typically reach 60 to 80 per cent of this under the best conditions. Multivane fans and Dutch-type windmills do somewhat less. Vertical-axis machines are not subject to the Betz limit; but there is still a limit, as we shall see. The value of this upper bound for vertical-axis machines is not exactly known; it depends to some extent on the type of vertical-axis machine.

The Vexing Problem of Storing Energy

Wind is an intermittant energy source. The problem of storing energy to supply the load when the wind subsides is a major stumbling block to many windpower applications.

The scope of this problem was demonstrated more than a decade ago by a medium-sized experimental wind system at Eilat, Israel, using lead-acid batteries for storage. A 2.5-kilowatt wind generator (138 volts, 20-m.p.h. wind) was used to power an intermittant load whose maximum was three kilowatts; lead-acid batteries with a total capacity of 21 kilowatt-hours (150 ampere-hours at 138 volts) were used in parallel with the load as storage. The wind generator and batteries each cost $1,100 (1952). The maximum daily output of the wind generator in the three-year period was 30.5 kilowatt-hours; the average was 17.5 kilowatt-hours. The battery was full on the average for 143 days a year.

The following table summarizes system operation during a three-year period:

	Kilowatt-hours per year	Net usable energy (kwh./yr.)
Total energy extracted from the wind	6,420	
Energy dumped because battery was full and load off	990	5,430
Energy dumped because of limitation on maximum battery charge rate	1,230	4,200
Energy consumed in battery system during charge and discharge	1,450	2,750
Net energy consumed in load	2,750	

The obvious conclusion is that lead-acid battery storage is expensive, wasteful of energy, and generally unsatisfactory. Though the battery cost as much as the wind generator, its capacity was sufficient to carry the full load for only seven hours. Only 43 per cent of the energy obtained from the wind reached the load; 57 per cent was consumed in the storage or had to be dumped. —*M.F.M.*

If the output of the wind machine is electricity, then some additional constraints to efficiency are present. The electrical generator has a certain power rating which may not be exceeded. For example, assume the generator is rated at 10 kilowatts, and the windmill blades are made long enough to drive this generator at its rated output when the wind is, say, 25 m.p.h. Then if windspeed increases, even for a short time, to 27.5 m.p.h. and the windmill delivers the increased power to the generator, the latter would be destroyed. To avoid this a feathering mechanism, or some other decoupling system, is used so that the windmill does not deliver more mechanical power than the generator can handle.

Continuing the example, if the wind drops below 25 m.p.h., say to 20 m.p.h., the power in the wind is reduced significantly, to $(20/25)^3$ or just over half of its previous value, and the electrical output from the generator will be much less than 10 kilowatts. The 25 m.p.h., at which the windmill is just able to drive the generator to its full rated power, is called the rated speed. Below rated speed the wind generator delivers less than its nameplate output; but even with winds above rated speed the output is exactly the rated output.

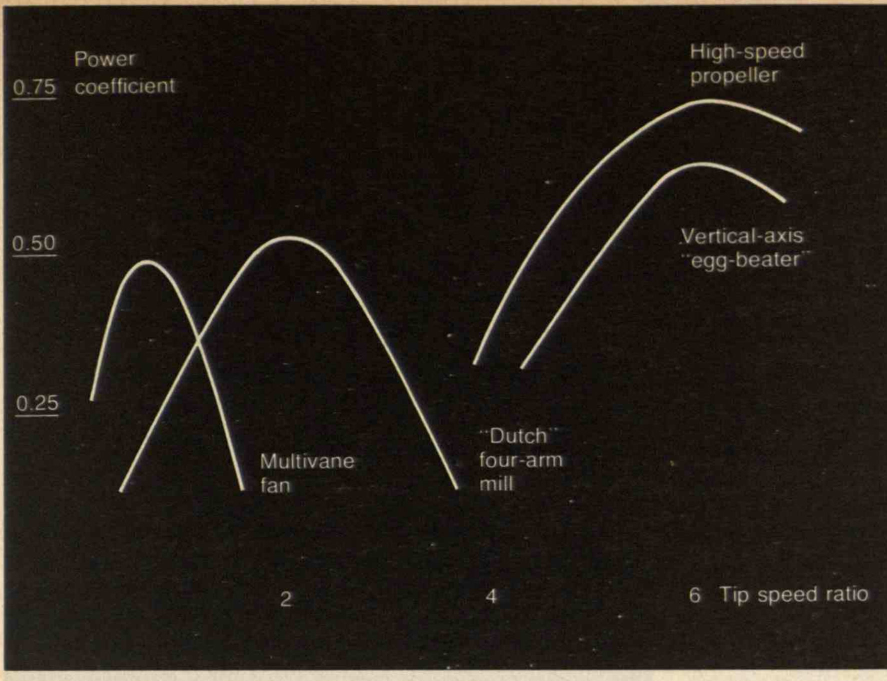
Small electricity-generating windmills, up to a few kilowatts' capacity, are typically connected to deliver direct current. Variable rotation speed of the windmill shaft is acceptable, since voltage output can be controlled by field modulation. Larger windmills, however, present two complications which essentially require that their rotational speeds be constant:

□ To be significant energy sources, large wind machines of 100 kilowatts and over will have to be integrated in large numbers into electric power networks. Each machine will thus have to deliver alternating current at the proper frequency, with controlled phase. This will require either a synchronous or induction generator; in either case, constant-speed rotation of the windmill is necessary. Variable-speed transmissions or d.c.-to-a.c. inverters, though technically possible, are not economically practical. The same is true — at least at present — of complex electronic devices to convert variable-speed shaft energy to constant-frequency a.c. power.

□ Large rotating machines with blades tens of meters in length must be erected on towers, and it is important that the rotation frequency of the blades does not match any of the structural resonances of the towers. If rotation speed is allowed to vary as windspeed varies, the structural resonances cannot be avoided.

The requirement of constant-speed operation is a source of significant inefficiency, because a windmill extracts energy from the wind at peak efficiency only when its speed of rotation bears a particular relationship to wind speed. Since wind speed is uncontrolled, the aerodynamic efficiency of the windmill is nearly always suboptimal if its rotational speed must be constant.

The rotor blade which is most efficient at extracting energy from the wind has both twist and taper, and possibly a variable airfoil section. Such a blade is more expensive to build than one of unchanging section which is neither tapered nor twisted. The cost of blades is a large part of the cost of the wind generator, and unfortunately the most cost-effective blade will not be the most efficient aerodynamically. The crucial figure is the amount of wind energy extracted per unit of capital expended; a more expensive blade is warranted only if the value of the extra energy extracted exceeds its extra cost. This may seem



Different types of wind machines differ in their optimum speeds and efficiencies. The multivane fan of the American midwest is most efficient when the tips of its blades are moving at about the speed of the wind (tip speed ratio = 1); it then has a power coefficient (the ratio of its power output to the maximum theoretically possible) of close to 0.50.

obvious, but experience has shown that engineers often have considerably more interest in seeking the most efficient design than in determining the most cost-effective compromise.

With proper protective systems, rotors will not fail by overspeeding in high winds. Corrosion and ice buildup may be problems in some locations, but the most likely cause of blade failure can be expected to be fatigue. A windmill is, actually, an example of a fatigue-testing machine. However, all experience to date indicates that rotor failure, by fatigue or otherwise, is not likely to be a serious problem. Structural failure of the tower seems more likely, but that problem can also be controlled *(see below)*.

Wind machines are extremely large in physical dimensions compared to other types of power generating equipment of the same rating. For example, a diesel-powered generator which supplies 100 kilowatts continuously when provided with 31 liters per hour of fuel weighs 1,740 kilograms and has physical dimensions of roughly 3 × 4.5 × 8 feet. The wind machine erected by N.A.S.A. near Sandusky, Ohio, which can supply 100 kilowatts only when the wind is blowing strongly (rated windspeed 18 m.p.h.), is a two-bladed propeller which sweeps a circle 125 feet in diameter with the hub being located on a tower at a height of 125 feet.

Supporting the Windmill in the Air Stream

Tower support stability is a major engineering consideration in any windmill. Usually towers and high structures are engineered for minimum wind loading; windmills are a case where the engineer desires maximum wind loading at the top of the tower. Even on small windmills the lateral force on the top can be very significant. For example, the force on a windwheel 15 feet in diameter in a 50 m.p.h. wind is a little over three metric tons. The engineer must design for the highest expected wind gust — the "once per century" condition. A difficult tradeoff arises because, in order to find the wind energy, it is normally desirable to raise a wind machine high into the air. Windspeed nearly always increases with increasing height. Data from anemometers at different heights on the same tower, over flat terrain, suggest that — on the average — increasing height from 100 feet to 150 feet means average windspeed increased by a factor of 1.18 and power by a factor of 1.6.

Tower cost is large, and the incremental cost of making a tower taller is also large. A serious effort to optimize tower height is justified, though there is as yet no systematic way to go about doing this. Present thinking is that cost effective towers should be only high enough to provide a reasonable ground clearance for the rotor.

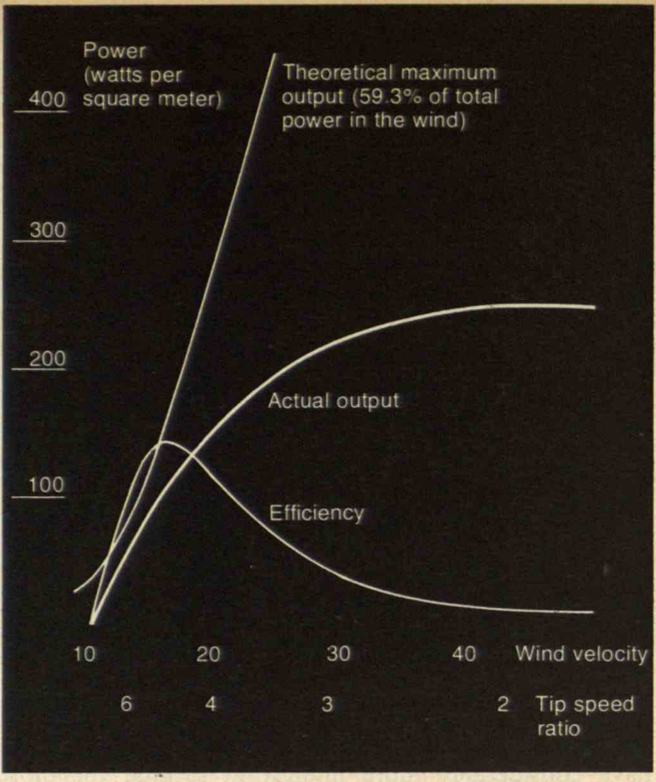
Large horizontal-axis machines often place the rotor downwind of the tower. When this is done each blade crosses the wind shadow of the tower once per revolution, and the resulting impulse loading complicates dynamic stability.

Vertical-Axis Machines

Although the first windmills were vertical-axis machines, no vertical-axis designs have ever been used on anything like the scale of the popular horizontal-axis types. Savonious rotors — invented, developed, popularized, produced and marketed in the 1920s and 1930s by the Finnish engineer of the same name — are perhaps the most familiar design. Recently the Darrius rotor (sometimes called "eggbeater") has been rediscovered, and it is presently regarded as among the most promising of the vertical-axis types.

Any vertical-axis design has the obvious problem of having to return the windcatching elements against the wind *(see diagram, page 37)*. This can be accomplished by shielding the returning elements with a windscreen, as in the Persian windmills; by hinging the elements ("articulating" them in the modern idiom) so that they present a large surface to the wind when traveling downwind and a minor surface when traveling upwind; by simply shaping them asymmetrically, as in the common cup anemometer; or by more subtle means. The blades in machines using the less subtle means enumerated, and some others as well, are caused to rotate because of a difference in drag forces between the

A hypothetical ideal horizontal-axis wind generator can extract 59.3 per cent of the power in the wind. However, no real machine reaches this efficiency, even when operating at its optimum tip speed ratio. The bold line shows the actual output of a 13-kilowatt windmill constrained to operate at a constant speed of rotation in order to generate electricity for a synchronous grid; efficiency falls sharply as the tip speed ratio departs from optimum.



downwind-moving and the upwind-moving elements. Machines of this type are limited in rotational speed by the condition that the downwind-moving elements cannot move faster than the wind. They are not very efficient in extracting energy from the wind and not very economical in use of materials, since the cross-section of material is larger than the cross-section of wind intercepted. The compensating advantage is simplicity and ability to respond to gusty winds of rapidly changing direction. The only applications of interest today are for vertical-axis machines of rather small scale.

The other class of vertical-axis machines is defined by the fact that more than the drag difference is used to power them; lift forces are also involved. These may properly be called vertical-axis turbines — indeed, the present government-type terminology is to call them V.A.W.T.s (Vertical Axis Wind Turbines). A familiar example of this type of device is the small vertical-axis ventilator commonly seen on the roofs of buildings. The Savonious rotor *(see page 37)* falls into this class unless the space between the two "wings" is blocked, in which case it is a differential drag machine. These two types of V.A.W.T. are, however, still not very efficient, and they are not economical in use of material.

The Darrius rotor, a most promising V.A.W.T. configuration, has only two or three thin blades, rotates quite rapidly (the speed of rotation depends on the diameter of the machine, but the outermost parts of the blades move at three or four times the windspeed) and is almost as efficient as a good horizontal-axis propeller (called a H.A.W.T. in today's language). The Darrius rotor will not self-start, but this is not a problem when it is connected to drive a generator, since the generator can be driven as a motor to get the rotor up to speed.

The major advantage of the V.A.W.T. over the H.A.W.T. is that the gearbox and generator can be on the ground, not at the top of the tower. This has a very beneficial effect on the cost of the structure. Also, there is no need for a mechanism to rotate the machine when the wind changes direction, which again simplifies design and saves money.

Large Wind Generators for Electric Power

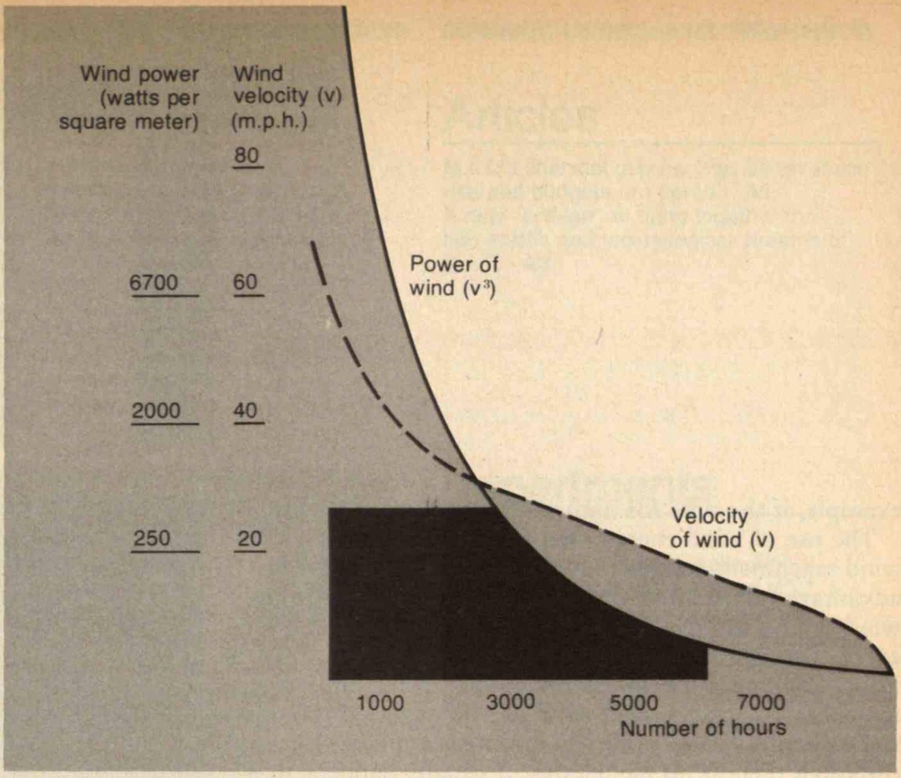
Wind energy has been harnessed for human needs by a very wide range of devices and applications — from sailing ships, ventilators, small battery-chargers for inaccessible places, and wind-driven pumps to very large wind generators for electric power, used as part of a regional or national electricity network. The smaller-scale applications already have had a large impact on human needs throughout the course of history, but the very large-scale machines are the ones which are the most exciting to contemplate.

There is a considerable history of attempts to use wind energy for electricity generation on a regional scale. Several European countries — notably Denmark, England, and France — have had large national programs in the past. A number of prototype and test units, all horizontal-axis, propeller-type machines, were built and operated for a few years in the 1940s and 1950s under these national programs. All were abandoned in the face of cheap and abundant Arab oil and projections of cheap and abundant nuclear fission energy.

But the largest of the large-scale prototype wind generators built anywhere to date was erected in the United States in the early 1940s as a private development effort. This was the Smith-Putnam wind turbine, a two-blade propeller with a 175-foot diameter swept circle, located on a rounded mountain called Grandpa's Knob in southern Vermont. The propeller drove a 1,250-kilowatt synchronous generator connected into the local power network. The wind generator, at rated output, represented about 10 per cent of the generating capacity of the utility system. The machine was operated intermittently for several years as a test unit, firming the design for the 100 production units which were expected to follow. At the conclusion of the test phase it was turned over to the utility for use as a regular generating station. Unfortunately it operated in this mode for only a few months. Failure was spectacular; a blade broke off at the root and was thrown a great distance. The fracture occurred at a point of known metallurgical weakness which could not be properly repaired because of wartime conditions. The 100 production units were never built, and the test unit was dismantled since the projected cost of the wind energy was greater than the cost of energy available from other sources.

In the 1970s interest has revived. Today the United States does have a national program — by far the most vigorous national program in the world at this time. The program focus for large-scale power-generating windmills is on horizontal-axis, two-bladed propellers, and the first of these, a test unit, has been running since late in 1975 near Sandusky, Ohio. Current plans call for installation of several more units in the next two years, all

How much wind power is available at any particular site, and how much of it can a particular wind machine utilize? A chart such as this answers both questions. The dashed line shows the distribution of the wind velocities measured during a typical year (8,760 hours) at a typical excellent wind power site; the solid line shows the distribution of available power, proportional to the cube of the velocity. The wind machine whose output is represented by the black area in this diagram is an ideal propeller-type wind generator with rated windspeed of 27 m.p.h. (The rated wind speed is that required for the generator to reach its maximum electrical rating; if wind speed is in excess of 27 m.p.h., the excess power is deliberately wasted, since additional power supplied to the generator will overload the electrical system.) The wind generator's "cut-in" speed, below which no power is generated at all, is 17 m.p.h.; and the "furling" speed — the windspeed at which the machine is automatically halted in order to prevent its destruction — is 60 m.p.h. Thus the black area is proportional to the energy which can be extracted by this ideal wind machine.



on utility systems at sites owned by utilities. The largest units now envisioned will have outputs of 1,500 kilowatts at rated windspeed. The swept circle diameter would be about 200 feet, somewhat larger than the Smith-Putnam machine. Such machines will have to be multiplied in large numbers to make an appreciable contribution to U.S. energy requirements. The hope is that after the government program shows the way and pays the research, development, and engineering costs, the wind generators will be inexpensive enough to make them competitive with other sources, and the multiplication will occur.

The first large wind generator to be connected into a utility system in recent years will, however, be in Canada, not in the U.S. It will be a vertical-axis Darrius rotor machine, driving a 200-kilowatt generator on the Magdalen Islands in the Gulf of St. Lawrence. The connected load in the system (a disconnected segment of the Hydro Quebec system) is 24,000 kilowatts, currently handled entirely by diesel generators, so the wind generator will be a minor fraction of the total. If successful, more wind generators will be added. The site is windy (annual average 20 m.p.h.), and diesel fuel is expensive ($15 per barrel, resulting in fuel cost of three cents per kilowatt-hour), and these two factors combine to suggest the economic viability of wind energy.

Environmental Impact

One of the obvious and important advantages of wind as an energy source is that environmental impact of its use is so small as to be virtually nonexistent. Indeed, one can hardly imagine a primary energy source with less environmental impact. The principal environmental insult will be that associated with the mining and processing of the materials, especially metals, used in construction. This will of course be present in any power generating scheme.

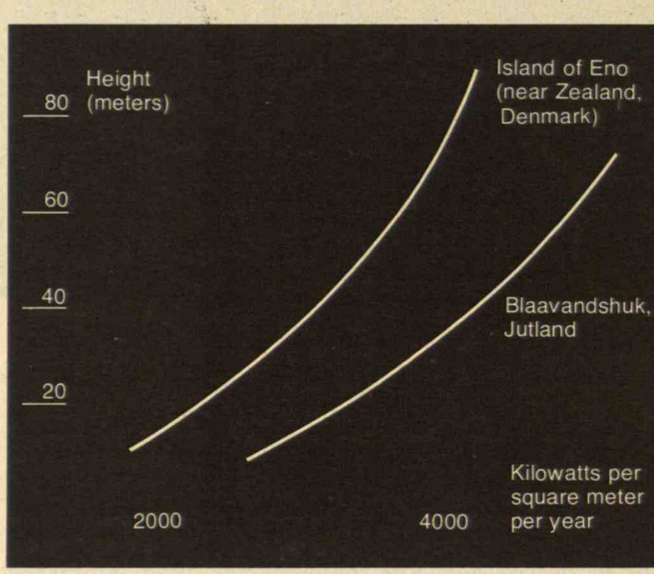
It is customary to catalog all conceivable environmental disturbances which could result from a new technology, widely applied. There are some environmental disturbances to be expected from wind machines, but the quantitative effect of these is expected to be so small as to be hardly noticeable. For example, climatic disturbance caused by extracting energy from the wind can hardly be greater than that we now tolerate routinely from buildings and tall trees, considering the maximum plausible numbers of wind machines and the small fraction of the moving airstream which will be intercepted. Blade noise should be minor, and large machines will be located far from human concentrations. Bird kill by impacting whirling blades has not been noted to date; in any case it should be negligible compared to other sources of bird mortality. Compared to the ecological disturbances associated with hydro, nuclear, and fossil sources, wind energy is absolutely clean.

Two problems sometimes mentioned are radio and TV interference and the visual effect of high towers unaesthetically cluttering the landscape. These are not environmental impacts in the sense of affecting the natural ecology of an area, though they may be undesirable from the standpoint of human activities.

Utilizing the Unsteady Wind

A most serious constraint to the use of wind power arises from the fact that wind is an intermittent energy source. Effective use requires an interruptible load, an energy-storage system, or a standby source able to respond on demand. The traditional uses of wind power — grinding grain, pumping water for livestock or irrigation — are all interruptable loads. To a very limited extent, an interruptible load may be created by designing high thermal inertia (insulation) or high mechanical inertia into the energy-consuming system. A wind-powered refrigerated warehouse can be regarded as an intermittent load, for

The power in the wind increases with height above the earth at most points; hence the concern of wind machine sponsors to elevate their machines on towers. But the forces on such towers are very large, and the cost can exceed the value of the extra energy to which they provide access.



example, if the time for natural warm-up is many days.

The use of wind energy on a standby basis, where the wind machine functions only as a fuel saver, has the disadvantage of requiring a capital investment for both the wind system and the standby system. In the same way, an energy storage system represents an additional investment which produces no energy; in fact, being imperfect, the energy storage system itself can be expected to consume energy. Water power is a more complicated case. Although there is no fuel charge, it usually happens that annual hydroelectric energy production is limited by availability of water. When wind generators are connected in parallel with a hydro station, water can be conserved when the wind generators are producing; thus the use of hydro in combination with wind may be a highly economic proposition. In fact, it would be correct to say that an electric utility with some hydro capacity in its system is in a substantially better position to use wind-generated electricity than one which does not, given the same amount of wind energy available in both cases.

Energy storage systems proposed for use with wind energy systems include electrochemical storage batteries (the only well-established system commonly used with wind generators today), flywheels, compressed air in underground caverns, hydrogen, and pumped hydraulic storage.

Under even optimum conditions electrochemical battery storage is very expensive in both capital cost and in energy loss. A 115-volt, 130-ampere-hour "stationary service" battery set costs about $650, or $43 per kilowatt-hour — a high price indeed when kilowatt-hours are worth only a few cents each. In addition, energy is dissipated in charging and discharging the batteries. If energy becomes available at a rate exceeding the maximum charge rate of the battery system (as in a strong wind), some of the energy must be dumped even though the storage is not full.

Among the various storage systems possible, there is today no real alternative to electrochemical batteries. Storage through hydrogen gas obtained from wind-generated electricity by the electrolysis of water has been studied and demonstrated on a small scale. Although feasible in a strictly engineering sense, the costs are much too high at present. Losses of energy are severe, and the cost of the necessary components adds substantially to the investment in the wind system.

Flywheels are not now an energy storage alternative, but very-high-strength materials, which have become available only recently, may make flywheel storage practical in the 1980s. The high-strength materials are important because energy stored increases with the square of rotation speed, and rotation speeds are limited by the ability of flywheel materials to withstand centrifugal stresses. One computation shows that a flywheel made of new high-strength fiber materials storing 15 kilowatt-hours would weigh about 91 kilograms (including the integral generator) and rotate at between 25,000 to 75,000 r.p.m.; it would fit into the engine compartment of a small car. Larger units, intended for electrical power storage at the substation level in existing utility systems, might utilize rotors 12 to 15 feet in diameter weighing 100 to 200 tons; at 3,500 r.p.m., the stored energy would be between 10,000 and 20,000 kilowatt hours.

The use of wind in connection with a substitute standby energy source is of more immediate practical interest. The key requirement is the availability of a reliable and controllable standby source capable of providing enough power to meet the maximum demand. This source must have low capital cost and offer unutilized generating capacity which can be called upon at any time. The Smith-Putnam wind turbine on Grandpa's Knob in Vermont was an example; it was connected with a public utility system which obtained power from a number of medium-size hydroelectric plants. When winds were strong and wind power output substantial, water was allowed to accumulate behind the various dams in the

MIT '77

Articles

Departments

Tackling the "Dynamic Imbalance" in M.I.T. Finances

After three years in which operating expenses have exceeded revenues and unrestricted income — in other words, years of operating deficits — there remains a "dynamic imbalance" in the Institute's finances which Paul E. Gray, '54, Chancellor, calls "the most difficult and intractable problem we face."

By "dynamic imbalance" he means the situation in which the Institute's expenses are growing faster than the revenues and funds to meet them. For example, even with vigorous efforts to prune budgets, operating expenses in 1975-76 were up 8.8 per cent over the previous year, to $269.3 million. Two of the four income streams available to meet these expenses — tuition and research revenues — increased comparably in 1975-76. But gift income and income on investments showed little change.

"Because these rates of growth are different," Dr. Gray told the faculty last fall in his annual report on the Institute's finances, the difference between income and expenses — the deficit — "tends to grow dramatically each year."

It is a persistent problem whose roots lie in the leveling and even decline of sponsored research volume (measured in constant dollars) between 1968 and 1975, in the tripling of energy costs in the fall of 1973, and in the nation's continuing "stagflation," in which high rates of inflation are accompanied by low rates of economic growth.

A Draw-Down of Capital That Costs $600,000 a Year

To offset the growing differential between expenses and revenues there have been significant budget restraints at M.I.T. for the past seven years — reductions which by now have totalled some $15 million. Only $4 million of this, about 25 per cent, came from academic budgets; $11 million was

Research Reimbursement at Stake?

Will federal agencies continue the "long-established principle" of reimbursing colleges and universities fully for both the direct and the indirect expenses of research under their sponsorship?

A federal task force is now studying the issue, in response to "federal pressures both within the Congress and in funding agencies . . . to mandate higher levels of cost-sharing by all universities participating in sponsored programs and to reduce the share of indirect expenses paid by research sponsors," Paul E. Gray, '54 Chancellor, told members of the faculty during his review of M.I.T.'s finances late last fall (*see left*). There is potential, he fears, for a "devastating effect" on M.I.T's budgets.

"We intend to make a maximum effort, by ourselves and in consort with other research universities, to preserve the policy of reimbursement for the full costs, direct and indirect, of sponsored research," Dr. Gray told the faculty. "It is important to understand that if federal policy moves significantly in the direction proposed by certain members of Congress and by persons within the Department of Health, Education, and Welfare, the Institute could lose as much as $2 to $3 million per year in recurring revenues.

"Such a change would, of course, have a devastating effect on the deficit."

Leadership Campaign at $89.7 Million

The $225 million Leadership Campaign, launched in April, 1975, to muster major new resources for M.I.T., stood at $89.7 million — 40 per cent of its goal — by mid-November, 1976. Of that total of gifts and pledges, $24 million is designated for new endowment, according to Howard W. Johnson, Chairman of the Corporation, reporting to the Corporation Development Committee on November 5; the five-year goal is $100 million in new endowment.

To emphasize the importance of uncommitted funds such as endowment income, President Jerome B. Wiesner cited for C.D.C. members the Institute's use of such funds "several years ago" to make possible the particle physics work of Samuel C. C. Ting, Professor of Physics, which led to his 1976 Nobel Prize in Physics (*see page 7*). Assuring this kind of future financial integrity and independence, Dr. Wiesner said, is the "most important single thing" he and others can do at this time. Accordingly, they are "giving the Campaign the highest priority in terms of time."

James B. Lambert, S.M. '39, Vice President for Resource Development, told the C.D.C. that some 30 per cent of the $225 million Campaign goal should come through gifts and grants from business and industrial firms. That's the task of Richard L. Terrell, Vice Chairman of General Motors Corp. (he studied in the Sloan School's Program for Senior Executives in 1958), who is now recruiting a National Business Committee of which he will be Chairman.

Some 40 per cent of the Campaign total will come from individual donors and 30 per cent from foundations. Over the five-year Campaign period the Alumni Fund is due to realize $26 million, according to James A. Champy, '63, Executive Vice President of the Alumni Association.

M.I.T. Finances

Copies of a detailed statement on "M.I.T. Finances: Recent Trends and Future Outlook," prepared by Paul E. Gray, '54, Chancellor, and others for discussion at the November, 1976, meeting of the M.I.T. faculty, are available on request. Write *Technology Review*, Room E19-430, M.I.T., Cambridge, Mass., 02139.

pruned from so-called "support" budgets — administration, physical plant, and such activities as the Summer Session, Medical Department, and student affairs. The budget for 1976-77 includes $3.3 million of such reductions.

But the imbalance persists. For the current year, 1976-77, expenses are budgeted to be $275.2 million, up 5.2 per cent. After all operating revenues are committed, there will still be need for $4.5 million to pay these bills. Of that, $3.4 million will come from gifts, grants, bequests, patent revenues, and facilities allowances; this leaves $1.3 million to be drawn from capital funds. That's better than the $2.6 million needed last year and $5.2 million in 1974-75. But it represents a depletion of the Institute's capital resources instead of the increases which were typical of the Institute's years of growth in the 1950s and 1960s.

The cumulative use of capital funds (including reserves) since 1972-73 has been $12.1 million. Those are funds "which, had they not been used to meet current operating expenses, would be generating about $600,000 per year in investment income," Dr. Gray told the faculty. Present spending has thus deprived the Institute of future income.

Enhancing the "Grey" Capital While Saving the "Green"

Dr. Gray told the faculty that M.I.T.'s budget for 1977-78 can be balanced — that is, that revenues can be increased and expenses decreased so that there will be no gap between them. Then come two more goals:

"To set aside each year some portion of the unrestricted funds received so that they can be used for capital purposes" — endowment, physical plant, or new educational programs.

And finally the hardest task: "to shape the Institute's finances so that the operating budget will be dynamically balanced — to move toward a condition in which the growth rates of revenues and expenses are, and remain, in balance over an extended period."

Dr. Gray said he is aware that annual budget cuts continued into the future can lead to "a decline in innovative activity and, ultimately, to decreases in quality on a broad scale." He's determined that this won't happen — that his financial goals be met "in ways that will continue to enhance the intellectual and academic strengths of M.I.T." And he drew on an expression credited to Walter A. Rosenblith, Provost: conserving the financial resources represents the "green" capital of the Institute; but there is also the need to enhance its "grey" capital — "the collective intellectual resources of the men and women on whom the future of the Institute depends."

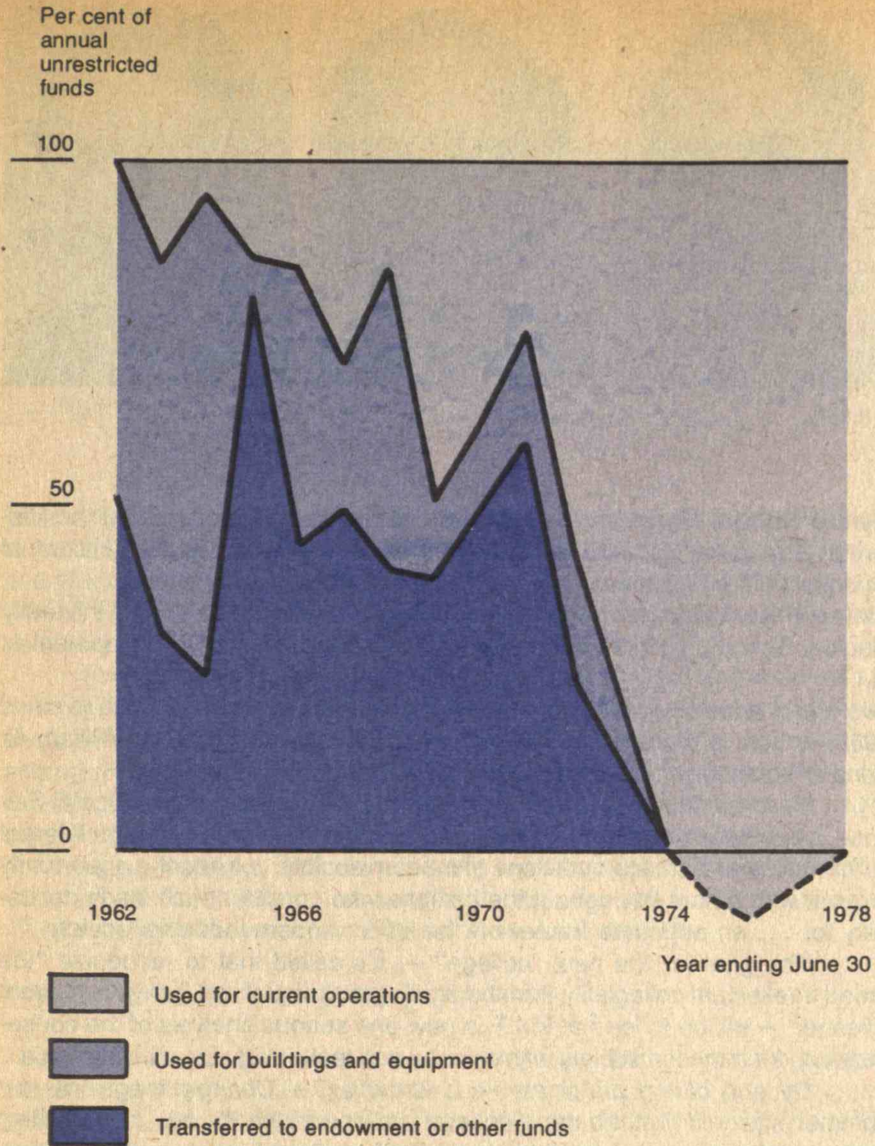
"Underendowed" by $200 Million

To balance M.I.T.'s budget for 1977-78 will require more hard decisions, and it will be possible only if the nation's rate of inflation remains moderate, if the Institute's research volume continues its recent modest growth, and if the income on M.I.T.'s present endowment base can grow at 3 per cent a year — which is to say that the $225 million Leadership Campaign meet its timetable for increasing M.I.T.'s invested funds.

The tough decisions: further reductions of about $2 million in budgets, continued increases in tuition, "minimum" increases in the use of unrestricted funds for undergraduate financial aid, and enrollment reaching 9,000 by September, 1977 — a 10-per-cent increase in four years.

The longer-term goal of a dynamic balance in M.I.T.'s finances depends on major changes in endowment and annual giving.

Dr. Gray proposed to the faculty that M.I.T. is "underendowed" by about $200 million; that is, he said, given the Institute's size and commitments, it should have another $10 million of annual investment income. Accordingly, Dr. Gray emphasized to the faculty the importance of the Leadership Campaign's goal of $100 million of new endowment by 1980 — "a tremendous help in insuring the future strength of the Institute," he said. — *J.M.*



Since 1962, more than one-third of the $103 million which M.I.T. received in unrestricted funds has been added to endowment; just over 20 per cent was used for buildings, and $44 million was used for current operations. But through the entire period there's been a trend toward using these resources for balancing the operating budget, and in the years ending in 1974, 1975, and 1976 an operating deficit had to be made up by drawing on unrestricted capital funds. Paul E. Gray, Chancellor, says the "significant improvement" since 1975 will continue; he projects a $1.3 million deficit in 1976-77 and a balanced budget in 1977-78. Then will come the goal of each year setting aside increasing amounts of the Institute's new unrestricted funds for endowment and new projects.

Education for the 21st Century: A New "College" of Humanities and Technology

How can the humanistic and technological streams of M.I.T. be brought together to help us better understand the vital issues of a technological society — the questions of value and choice which define our present and future, and over which technology has such a subtle but commanding influence?

A new answer to this vexing question — it has been a central preoccupation of many at M.I.T. since the inauguration of President Jerome B. Wiesner in 1971 (and even before) — was proposed late last year by a major faculty study group led by Elting Morison, Elizabeth and James Killian Class of 1926 Professor in the School of Humanities and Social Science. It is now being implemented in a "college within a college" — an informal grouping of faculty and students whose goal, in President Wiesner's words, is simply "the study of technological society."

Three distinguished scholars have already joined the School of Humanities to work in this new "college":

Intregrating Science and Humanities

For President Jerome B. Wiesner, the beginning of the new "college for the study of technological society" fulfills a goal cited in his Inaugural Address as 13th President of M.I.T. in 1971. He spoke then of M.I.T. students' capacity and great desire to "develop broadly in all spheres — moral, social, intellectual, and political. . . .

"New cooperative ventures involving the social sciences and humanities should draw disparate disciplines closely together and in so doing provide opportunities to create exciting new forms of professional education. Thus — by integrating science and technology with the study of man and his culture — can we recast the concept of a liberal education in a contemporary mold."

C. Kaysen

G. Holton

K. Keniston

L. Marx

Carl Kaysen: Helping Us Understand "How Our Society Manages Itself"

Carl Kaysen, a noted political economist who has been Director of the Institute for Advanced Study at Princeton, N.J., for the past decade, is now David W. Skinner Visiting Professor in the School of Humanities and Social Science.

He'll be associated with the new program on questions of societal value and choice (*see right*) in the School of Humanities, and Dr. Kaysen will teach two undergraduate courses during the coming term — one a historical study of government-business relations in the U.S., the other on economic, political, and social inequalities in the U.S.

President Jerome B. Wiesner, who announced Dr. Kaysen's appointment, said he "will strengthen our commitment to the study of some of the central problems of modern society . . . in order to gain deeper insights into the whole process by which our society manages itself."

It was under Dr. Kaysen's leadership — he has been Director of the Institute for Advanced Study since 1966 — that a new School of Social Science was organized in Princeton; Dr. Kaysen, having retired as Director, will return to that School.

Formerly at Harvard, Professor Kaysen was Deputy Special Assistant for National Security Affairs under President John F. Kennedy from 1961 to 1963, when he worked on the 1963 nuclear test ban treaty. Since then he has studied and written on a number of issues concerned with social policy and social change.

Gerald Holton, Mallinckrodt Professor of Physics and Professor of the History of Science at Harvard, is Visiting Professor of Physics and the History of Science at M.I.T. this year.

Kenneth Keniston, formerly Professor of Psychiatry in the Yale University Medical School, is Andrew W. Mellon Professor of Human Development at M.I.T.

Leo Marx, a leader in the field of American studies at Amherst College since 1958, is now a member of the M.I.T. School of Humanities as William R. Kenan Professor of American Cultural History.

Harold J. Hanham, Dean of the School of Humanities and Social Science, says these three have come to M.I.T. because of their common interest in "the value and choice questions of modern society. . . . and the opportunity to work with others throughout the Institute who consider such study necessary for . . . an adequate framework for life in modern industrial society."

The goal for the new "college" — it's called that to recognize "the broad intellectual collegiality that the study group visualized," says President Wiesner — will be to lead at M.I.T. a new and serious analysis of the consequences for man of a society with science and technology as a driving force.

By one of the principals — unidentified — *Change* magazine last summer was told that the new "college" is "one of the the few new exciting ideas in education — at least since the 14th century." He described its purpose as to "establish bonds at right angles to each other, to create, in other words, a super diamond. The difference between an ordinary hydrocarbon and a super diamond, after all, is simply one of bonding."

"A College for the Study of Technological Society"

Professor Morison's study commitee — an informal grouping of members of the faculty who consulted with more than two score distinguished experts from outside the community — worked for nearly three years on the plans that are now being implemented.

The consensus was that nowhere in the U.S. is there an undergraduate program which provides an adequate framework for life in modern industrial society and that, among U.S. institutions, M.I.T. may be uniquely equipped to develop such a program.

The goal: to provide students with a thorough grounding in science and technology and a comparably thorough sense of the humanities and social sciences — in a sense the modern equivalent of the traditional liberal education. "For only if society pays heed to the structures of power, custom, thought, and expression as they have developed and — as well — to the current nature of the human condition can it hope to make the fullest use of science and technology," says one description of the committee's recommendation.

The committee paid little heed to the organizational form appropriate to support this new endeavor, and the words "college" and "forum" have


H. J. Hanham


E. Morison

been used simply because they have no present organizational connotations at the Institute. As it is working out, Professors Morison, Holton, Keniston, and Marx are providing an initial nucleus for what is now called "the college," around which they expect an increasingly lively participation by other members of the faculty.

President Wiesner himself has noted the broadening interests of many M.I.T. faculty into areas "where the solutions appear to depend on the useful intersection of a variety of factors — political, economic, technological, and scientific." Indeed, the number and variety of these, he told members of the Corporation's Development Committee last fall, now suggest "a dispersion of energy which has been a source of considerable frustration."

Now, he thinks, there is a rallying point for those interests, for those who "sense that solutions for many of the existing problems depend upon more satisfying fusions of our different kinds of knowledge . . ."

Integrating the Undergraduate Experience

The new "college" is making a modest beginning this year, "using current resources such as unfilled chairs and existing educational programs as a springboard," as Dr. Wiesner expressed it for the C.D.C. For this year, Professor Morison says he will be satisfied to develop "a trial curriculum for a limited number of undergraduates." Its goal: "A more substantial integration of science and engineering on the one hand, and the humanities and social sciences on the other hand, than has been possible so far."

Professor Morison first taught at M.I.T. in the field humanities in 1946, when he was beginning research and writing which have since won for him wide acclaim in the field of modern American history — especially the effects of the Industrial Revolution on more recent scientific and technical progress. At Harvard since 1945, Professor Holton is known for work in molecular physics and the history of science — and especially for developing a science course for nonscientists which has become "a model at universities throughout the country," says Dean Hanham.

Professor Keniston is a student of modern America, author of widely respected studies of the attitudes of modern American youth. He has been Chairman and Executive Director of the Carnegie Council on Children, and Dean Hanham says he is "an excellent choice to contribute to a study . . . of the problems and possibilities of a society based on technology." Professor Marx, whose degrees are in the field of American civilization, is author of *The Machine in the Garden* — a book which, says Dean Hanham, "deals with precisely the questions that M.I.T. is concerned with regarding the accommodation of technology in our society."

The first courses of the "college," given last fall, were "Aspects of the Scientific Imagination" by Professor Holton, "Youth Movements" by Professor Keniston, and "Literature and National Experience in the U.S." by Professor Marx. — *J.M.*

"Openness to the Role of the Humanities and Social Sciences . . ."

Kenneth Keniston, whose appointment as Andrew C. Mellon Professor of Human Development puts him in the middle of M.I.T. efforts to fuse a closer relationship between the sciences and the humanities (*see left*), likes what he sees at the Institute.

After about a year at M.I.T., he told Nina McCain of the *Boston Globe* late last fall, he finds that "a significant group (of students) here is getting skills so they'll be able to do things in society. And they're also interested in the social meaning of what they're doing."

To Professor Keniston, whose books have made him an authority on the political and social concerns of college-age Americans in the 1950s and 1960s, that's unusual — almost unique. It's true, he told Ms. McCain, that most students now "are just as disillusioned with society, if not more so, as they were in the late 1960s." But there's a difference, he said. A decade ago many students "felt they could change the country fast." They soon enough discovered that was unrealistic, and now "the commitment to political, social action has fallen off to the point of disappearance."

But not at M.I.T., he finds. People here "think harder about the education of scientists and engineers than they do at most liberal arts colleges . . . One of the exciting things at M.I.T. is the openness of the faculty and administration to the role of the humanities and social sciences in education and human life."

These caricatures of misshapen M.I.T. "tools" — humpbacks, vampires, and gorillas — are actually costumed M.I.T. undergraduates — candidates in the 1976 "Ugliest Man on Campus" contest. For a full week last November they turned pan-handlers, throwing good manners as well as good looks to the winds, parading into class-rooms and intruding on meals and conferences to collect dimes and dollars for the American Cancer Society. Brian G. Hughes, '77, costumed as a vampire, gained publicity — and votes — by giving blood in the annual campus Red Cross drive (*opposite page*), but to no avail; The winners were the two-man team of Lawrence E. DeMar, '79, and David R. Brown, '78, as "The Hump." It was the most successful U.M.O.C. competition in history — $7,273.69 to the American Cancer Society, more than double the previous record of $3,083.83. (Photos: Gordon R. Haff, '79, from *The Tech* and Cathryn M. Chadwick)

A Gastronomic Campus Survey: Who Eats Where, Why, and How Much?

If you sign up for three meals a day five days a week in an M.I.T. dining hall — Walker, Lobdell, Baker, or MacGregor — this year, the cost is $5.95 a day. Add $8.92 for the two weekend days, when there's service only in Lobdell. Or buy a coupon book with 268 points in it; dinner costs four points, lunch three, and breakfast one — which works out to $3.66, $2.74, and $.91, respectively. However you do it, there are "unlimited seconds," and that advantage — "infinite food" — is what won Steven L. Horn, '79, (and lots of his colleagues, he thinks) to "Commons" this year.

Daniel A. Nathan, '80, of *The Tech* found other reasons among other "Commons" advocates in a survey late last fall. "I'm too lazy," said David Jacobs, '80, about doing his own cooking. Scott Bernard, '78, said he enjoys "Commons" "as a time to be social."

Some 1,130 students signed up for "Commons" last fall; that's about one-third of those living in Institute Houses and apartments on the campus. Most of the others put together their own meals for themselves — in kitchens in New House, MacGregor, Burton House, and Bexley Hall, on hotplates and in toaster ovens where kitchens aren't available. Sharon Lowenheim, '80, gave up "Commons": "I couldn't pick and choose; I couldn't go out and eat when I wanted to," she told Mr. Nathan. Lauren Turkanis, '78, likes to cook, and "I can eat what I want when I want it." Mr. Nathan thinks that "do-it-yourself" cooks spend as much as $15 a week for food.

"It's Own China and Silverware . . ."

To the Editor:

"If you're invited to dinner at an M.I.T. fraternity this fall, don't be surprised . . . to be served on M.I.T. Food Service china . . ." (*see October/November, page A15*) is completely unjustified slander.

As most fraternities offer fairly complete meal plans, it is rare that any of their members eat a Dining Service facility. This being the case, they lack opportunity to "lift" Dining Service tableware.

My own fraternity has a complete set of its own china and silverware, none of which bears any particular resemblance to that used in "Commons." As does Dining Service, we lose a certain quantity of it each year — to breakage, but not to theft.

I believe that it would be proper for *Technology Review* to offer an apology to the M.I.T. fraternal community for this uncalled-for slur.
Scott D. Tobias, '77

Mr. Tobias is Chancellor of Tau Epsilon Phi; the Editors hope that his legitimate request is fulfilled by this publication of his letter. — J.M.

"At Least 25 Grams of Protein"

Most fraternities offer 15 meals a week, some as many as 21 (Sigma Phi Epsilon). At Pi Kappa Alpha, members who apply for the job are paid to do the cooking, and seven dinners (plus use of the open, stocked kitchen for breakfasts and lunches) cost $19 a week.

Lambda Chi Alpha hires two cooks who serve two meals daily except Sunday; the bill is about $70 per month. Kappa Sigma serves two meals seven days a week, and Steve C. Brigham, '78, House Steward, insists that every dinner has "at least 25 grams of protein" (Mr. Brigham's major is nutrition and food science).

It may not be Joseph's or the Top of the Hub, but Mr. Nathan concludes that students do well enough. Dining at McDonald's — "a restaurant of dubious quality," he says — would cost at least $5 a day.

People

J. S. Collins

Alumni Director for the Midwest

Joseph J. Collins, who has been Special Assistant in the Office of the Chairman of the Corporation since 1969, is now Regional Director for the Midwest of the Alumni Association; he'll have responsibility for activities in an area including Montreal, Toronto, Chicago, Detroit, Cleveland, and Minneapolis/St. Paul, where he will provide support for Alumni Fund, club, and alumni relations activities.

Mr. Collins studied at the U.S. Naval Academy (B.S., 1963) and served in ship- and shore-based Navy assignments before coming to M.I.T.; he's now Lieutenant Commander in the Naval Reserve. His previous M.I.T. responsibilities have been in the field of community relations; he has served as Executive Secretary of the M.I.T. Community Service Fund, and he is Vice President of Cambridge Community Services, Inc.

All-Florida at Orlando

Alumni from throughout Florida will gather at Orlando's Hyatt House on February 19 for the second Florida Festival, an all-Florida alumni meeting. Among the speakers:

☐ Harold E. Edgerton, Sc.D. '31, Institute Professor, Emeritus, on investigations at Loch Ness.

☐ Robert W. Mann, '50, Whitaker Professor of Biomedical Engineering, on new health care developments.

☐ Jerome B. Wiesner, President of M.I.T., on Institute developments.

☐ Harvey C. Jones, S.M. '50, Director of the Reedy Creek Utilities Co., on "Behind the Scenes at Walt Disney World."

Mr. Jones' company operates 11 utilities serving Walt Disney World, and Mr. Jones is himself a member of the Operating Committee of Walt Disney World Co. He'll conduct a "backstage" tour of Disney World operations for Festival visitors on February 20.

For further information, write Peter C. Hand, '48, 610 Gaines Way, Winter Park, Fla., 32789.

Individuals Noteworthy

Counselors: Officers, Directors, Advisors

William R. Prindle, Sc.D. '55, former Vice President in charge of research at American Optical Co., to Executive Director of the National Materials Advisory Board of the National Research Council's Commission on Sociotechnical Systems ... **George Freedman,** '43, Manager of the New Products Center of Raytheon's Microwave and Power Tube Division, to Chairman of the Board of Governors of the International Microwave Power Institute ... **David R. Clare,** '45, former Vice Chairman of the Executive Committee of Johnson & Johnson Co., to President and Chairman of the Executive Committee of the Board of Directors.

William N. Johnston, '50, Vice President of the American Bureau of Shipping, to Senior Vice President ... **Burton D. Figler,** '58, Principal Engineer with Aerodyne Research Inc., to Winthrop Community Chairman for the 1976 United Way of Massachusetts Bay ... **William J. Wiesz,** '48, President and Chief Operating Officer of Motorola, Inc., to Vice Chairman of the Board of Governors of the Electronic Industries Association ... **Samuel Rabinowitz,** '40, to treasurer of United Community Planning Co.

Edwin W. Hiam, '48, investment advisor with the Boston firm of Foster Dykema Cabot & Co., to Vice President of the Board of Trustees of Boston's Museum of Science ... **A. Wentworth Erickson, Jr.,** '28, former President of West India Chemicals, Ltd., to Vice Chairman of the Wentworth Institute/Wentworth College of Technology Board of Trustees ... **Phyllis A. Wallace,** Professor of Management at the Sloan

School of M.I.T., to Trustee of the Museum of Fine Arts of Boston.

Kudos: Honors, Awards, Citations

To **George P. Shultz,** Ph.D. '49, former Secretary of the Treasury, the Legion of Honor decoration from the French Government . . . to **Robert C. Seamans, Jr.,** S.M. '42, Administrator of the U.S. Energy Research and Development Administration, an honorary doctor of laws from Lehigh University . . . to **Nathan Cohn,** '27, former Director of Leeds & Northrup Co., North Wales, Penn., the distinction of Honorary Member of the Instrument Society of America . . . to **B. J. Steigerwald,** S.M. '56, Deputy Assistant Administrator for Air Quality and Standards of the U.S. Environmental Protection Agency, the award of Federal Environmental Engineer of the Year by the Conference of Federal Environmental Engineers.

To **Marc D. Levenson,** '67, Assistant Professor of Physics and Electrical Engineering at the University of Southern California, the Adolph Lomb Medal by the Optical Society of America . . . to **Shri N. Singh,** S.M. '66, Senior Research Metallurgist at U.S. Steel Research Laboratory in Monroeville, Penn., the Alfred Noble Prize from the American Society of Civil Engineers . . . to **Jack H. Westbrook,** Sc.D. '49, Manager of Materials Information Services at the General Electric Research and Development Center, the honor of 1976 Campbell Memorial Lecturer by the American Society of Metals.

Edward A. Boyle, Ph.D. '76, and **Joan V. Ruderman,** Ph.D. '74, have been selected as 1975-76 N.A.T.O. Postdoctoral Fellows for study abroad.

Administration:

Anne E. Thompson, former Assistant Dean for Student Affairs, is now in a graduate program in clinical psychology at the University of Michigan.

Obituaries

William H. Brown, 1910-1976

William Hoskins Brown, '33, Associate Professor of Architecture, Emeritus, who was affiliated with the Department of Architecture for 40 years — 36 of them as a member of the faculty — died on November 5 in Phoenixville, Penn. He was 67.

Professor Brown came to M.I.T. to study architecture after completing undergraduate work at Oberlin College; he returned to the classroom in the 1930s to start work on his M.Arch. degree, awarded in 1942. Meanwhile, he had joined the teaching staff and, shortly after World War II, founded his firm of William Hoskins Brown Associates, Inc.

For M.I.T., Professor Brown designed the refurbishing of the former Lever House at 50 Memorial Drive for the Sloan School of Management and Faculty Club. As leader of his firm Professor Brown was responsible for designing schools and housing for the elderly in Massachusetts and New Hampshire. But his greatest distinction came through his coordination of an architectural team from the M.I.T. Department of Architecture in the design of 100 Memorial Drive, an innovative, widely honored apartment house adjacent to the campus.

Deceased

Carroll W. Brown, '99; October 5, 1976; 531 Central Rd., Rye, N.H.
Lester F. Miller, '01; May 21, 1976; 844 Stevely Ave., Long Beach, Calif.
John W. Ager, '04; October 1, 1976; 145 Camellia Cir., Birmingham, Ala.
C. Dean Klahr, '05; September 26, 1976; 1608 South Shore Dr., Erie, Penn.
James H. Fenner, '07; February 10, 1965
Ruth M. Denny, '08; June 5, 1972
Charles A. Edmonds, '08; December, 1965
Harold H. Howland, '08; July 16, 1976; 5415 Connecticut Ave. N.W., Washington, D.C.
Thomas H. White, '08; July 11, 1975; R.D. #1, Colchester, Vt.
William J. Pead, '11; July 16, 1976; 15 Beverley Ave., Mount Royal, Quebec, Canada.
Seymour J. Spitz, '14; July 7, 1976; 511 West Blount St., Pensacola, Fla.
Edward E. Alt, '15; April 2, 1976; 505 Lake Shore Dr., Chicago, Ill.
Orton P. Camp, '15; August 12, 1976; 129 Wheeler Rd., Middlebury, Conn.
Edward R. Hall, '16; July 17, 1976; 2 Over Ridge Ct. #3721, Baltimore, Md.
Theodore W. Burkhart, '17; April 16, 1975; 4708 Fieldcrest Ave., Portland, Ore.
Charles W. Dow, '18; July 3, 1976; 12 Phillips Ave., Rockport, Mass.
Saxton W. Fletcher, '18; August 13, 1976; Fletcher Hill, Greenfield, N.H.
Joseph A. Kelley, '18; February, 1976; Meadowlark Dr., Box 27, Tryon, N.C.
Frederick C. Fischer, '20; September 16, 1976; 1400 Low Rd., Kalamazoo, Mich.
Henri S. Lench, '20; August 23, 1976; 442 James #7, Dunedin, Fla.
Walter E. Church, '21; July 15, 1976; Box 52, Arch Cape, Ore.
John R. Gallimore, '21; September 17, 1976; 3618 Rolliston Rd., Cleveland, Ohio.
Albert J. Hanley, '21; September 19, 1976; 20 Steere St., Harrisville, R.I.
Percival C. Keith, Jr., '22; July 9, 1976; Box 311, Peapack, N.J.
Wilhelm D. Styer, '22; February 26, 1975; 900 Glorietta Blvd., Coronado, Calif.
F. Willett Walton, Jr., '22; September 20, 1976; Dodge Rd., North Edgecomb, Maine.
William J. Lutz, '23; December 27, 1974; c/o Short Hills Village, Forest Dr., Apt. 73A, Springfield, N.J.
Edmund H. Miller, '23; September 9, 1976; 27 Buffard Dr., Rochester, N.Y.
Eugene V. Ward, '23; February 2, 1976; 627 Salvatierra St., Stanford University, Stanford, Calif.
J. Harvey Westren, '23; February 1, 1976; 33 Glenrose Ave., Toronto, Ontario,

Canada.
Albert C. Shue, '24; January 7, 1976; 215 Park Row, New York, N.Y.
Hyman H. Stutman, '24; October 8, 1976; 41 Park St., Brookline, Mass.
Edward F. Dirks, '25; September 17, 1976; 236 Memorial Ave., Haddonfield, N.J.
Ralph Ilsley, '25; June 8, 1976; 4400 Davenport St., N.W., Washington, D.C.
John R. Kelley, '27; September 19, 1976; 1215 Cima Linda Ln., Santa Barbara, Calif.
Robert A. Lavers, '27; April 5, 1975.
Kenneth M. Barney, '28; September 27, 1976; 901 Shore Rd., Linwood, N.J.
Archibald W. Adkins, '29; August 28, 1976; 37 Clarissa Rd., Chelmsford, Mass.
Jacob G. Mack, '29; April 15, 1976; 111 Walnut Hill Rd., Chestnut Hill, Mass.
Edward J. Partington, '29; September 29, 1976; Palm Beach Park, 111 Ocean Dr., San Clemente, Calif.
Edward Depoyan, '30; July 21, 1976; 410 39th Ave. N.E., St. Petersburg, Fla.
Webster E. Fisher, '30; September 15, 1976; 691 Oakridge Dr., Rochester, N.Y.
Tashizo Komamura, '30; January, 1976; 4621 Ohitakioji Cho, Shinagawa Ku, Tokyo, Japan.
Lawrence L. Lovett, '31; October 7, 1976; 35 Leicester Rd., Belmont, Mass.
A. Morton Plant, '31; October 12, 1976; 1020 Grove St., Evanston, Ill.
Joseph A. Kane, '32; October 5, 1976; 31 Farragut Rd., Swampscott, Mass.
Thomas E. Sears, '32; August 7, 1976; 770 First Parish Rd., Scituate, Mass.
J. D. Billingsley, '33; May 23, 1976; 701 Hilltop Ln., Westmont, Fredericksburg, Va.
Samuel C. Prescott, '33; September 10, 1976; Box 35, Rt. #1, Auburn, N.H.
George F. Gales, '35; July 26, 1976; 46 Stoney Brae Rd., Wollaston, Mass.
Roger S. Warner, Jr., '35; August 3, 1976; 1435 4th St. S.W., Washington, D.C.
Henry Knippenberg III, '39; July 11, 1976; 3336 Westbury Dr., Columbus, Ohio
Robert L. Millar, '40; November 6, 1975; 29 Colonial Dr., Montpelier, Vt.
Franklin W. Kolk, '41, August 3, 1976; 164 Du Bois Ave., Sea Cliff, N.Y.
Arnold F. Kluever, '42; October, 1973; 921 Ravlin Rd. S.E., Huntsville, Ala.
Alice E. Butler, '43; January 21, 1975; 1104 Main St., Norwell, Mass.
Harry M. Simpson, '48; September 16, 1975; Box 25, Valley Center, Calif.
John E. Bent, '50; September 30, 1976; 39 Hastings Rd., Ashburnham, Mass.
Werner I. Frank, '53; July 22, 1976; 114 Waban Hill Rd. N., Chestnut Hill, Mass.
Gustaf E. Lofgren, '56; May 7, 1973; Bridle Path Ln., Riverside, Conn.
Norman W. Schaefler, '59; February, 1974; 1411 N. Fuller Ave., Los Angeles, Calif.
Max J. Reinhart, '66; January 28, 1975; 3305 Woodland Pkwy., Columbus, Ind.
Barry Laks, '70; July 27, 1976; 200 Swanton St. #729, Winchester, Mass.
Stewart Frost, '71; July 27, 1976; 955 Quinn St., Boulder, Colo.
Alan L. Precup, '73; September 18, 1976; 430 Heywood Ave., Aurora, Ill.

Courses

I
Civil Engineering

With the Alumni

Roger E. A. Arndt, Ph. D. '62, was appointed Director of the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota. He is also a professor in the Department of Civil and Mineral Engineering. . . . **Tom Parody,** S.M. '72, received his doctorate in civil engineering from the University of Massachusetts last year and is now working as a senior research assistant at Charles River Associates in Cambridge . . . **Thomas F. Gilbane, Jr.,** M.S. '75, has been appointed Vice President-Manager of Gilbane Building Company's newly-opened Cleveland, Ohio, office. He and his wife, Mary, will live at 2205 Demington Dr. in Cleveland Heights. . . . **Roger Foott,** Sc. D.'73, is preparing a book on soil behavior and its applications in engineering practice in collaboration with Professor Charles C. Ladd and Professor T. W. Lambe of the Department of Civil Engineering at M.I.T.

Charles C. Noble, S.M. '48, Vice, President of Domestic and International Special Projects for the Boston-based engineering firm of Chas. T. Main International, Inc., has been elected to their board of directors . . . **Thomas Regan, Jr.,** S.M. '68, has been appointed Director of Public Works, Howard County, Md. . . . **Francis H. Sayles,** '49, Research Civil Engineer in the U.S. Army Cold Regions Research and Engineering Laboratory, will participate in a two-month exchange program established by the U.S. National Academy of Sciences and the Academy of Sciences of the U.S.S.R. He will work with the U.S.S.R. Permafrost Institute in Siberia . . . **Robert F. Seedlock,** S.M. '40, Major General of the U.S. Army, retired, has been awarded the Engineer of the Year Award of the Metro-Atlanta Engineers. He is presently Southeastern Regional Manager for the new engineering firm of Parsons, Brinckerhoff, Quade and Douglass.

II
Mechanical Engineering

James E. Hubbard, '77, has been chosen for the 1976 Scott Paper Company Foundation Award for Leadership. He'll receive $2,000 stipends for his senior year and his first year of graduate work, and the Department receives a $2,000 unrestricted grant.

The Scott award recognizes a "high level of scholarship and noteworthy success in extracurricular activities"; Mr. Hubbard is Chairman of the Northeast Section of the National Society of Black Engineers, and he's been a major factor in revitalizing BlackME, an M.I.T. organization founded in the early 1970s to benefit minority students in the Department.


Thomas A. Keim


A. H. Rasegan

With the Alumni

Thomas Zebehazy, S.M. '72, is now Senior Experimental Engineer in the Engineering Analysis Department of Chevrolet in Warren, Mich. . . . **Thomas A. Keim,** S. D. '73, has joined the General Electric Research and Development Center as a mechanical engineer . . . **Alexander H. Rasegan,** S.M. '67, is chief engineer for engines at the Chevrolet Motor Division in Detroit, Mich. . . . **Vikram N. Mehta,** '44, is a senior executive in the industrial house of Mahindra and Mahindra Ltd., located in Bombay, India. They are engaged in the manufacture, sale and distribution of a wide variety of items, some of which include: automobiles, alloy steels, textile machinery, elevators, fiberglass products and industrial electric equipment.

George Becher, '54, is returning to the American Pad & Paper Co. in Holyoke, Mass., after eight years as their Utah plant manager; he will be Director of Corporate Engineering . . . **John H. Midney,** '47, has the new position of Assistant Secretary of Emhart Corporation and General Attorney of Emhart Industries, Inc.

III
Materials Science

With the Alumni

Shri N. Singh, S.M. '66, was awarded the Alfred Noble Prize of the American Society of Civil Engineers for his paper, "Mechanism of Alumina Building in Tundish Nozzles During Continuous Casting of Aluminum-Killed Steels." He is presently a senior research metallurgist at the U.S. Steel Research Laboratory in Monroeville, Penn. . . . **William R. Prindle,** Sc.D. '55, has been named Executive Director of the National Materials Advisory Board of the National Research Council's Commission on Sociotechnical Systems . . . **William G. Morris,** S.M. '63, has joined the General Electric Research and Development Center as a metallurgist. He lives in Rexford, N.Y., a suburb of Schenectady.

An Act of Faith Spawns a Profession

There were only four M.I.T. alumni — all from the Physics Department — working as electrical engineers when the first curriculum in electrical engineering in the U.S. was established at the Institute in 1881. The new program, championed by Professor Charles R. Cross, '70, Head of the Physics Department, was an act of faith — "created more in anticipation of what was expected to develop than to meet an already existing need," writes Dr. Frederick E. Terman, Sc.D. '24.

The sponsors' confidence was justified: by 1892 27 per cent of M.I.T.'s graduates earned degrees in electrical engineering, and ever since then the Department has been the largest — in terms of enrollment — of any at the Institute.

Graduate study in electrical engineering remained a rarity until after World War I and doctorate work until after World War II. When Dr. Terman was a graduate student at M.I.T., only one member of the Department's faculty had an earned doctorate and only a few had Master's degrees.

Dr. Terman records a substantial discontinuity in M.I.T.'s production of Master's degrees in 1922, when the annual average moved from five (prior to 1922) to 40 (balance of the 1920s). The difference was M.I.T.'s pioneering cooperative program with the Lynn works of General Electric Co., where Elihu Thomson, President of the Institute, was in charge. It was "extremely successful" from the very start, says Dr. Terman — yet never copied in detail by other institutions.

During the 1920s a college professor was considered "productive" if he and his students turned out one technical paper of professional quality every two years. By this definition, writes Dr. Terman, there were eight "productive" electrical engineering teachers on U.S. faculties during the six-year period starting in 1920, and three of these were at M.I.T.

These are among the highlights of Dr. Terman's history of electrical engineering education in a special bicentennial issue of I.E.E.E.'s *Proceedings* (September, 1976). He's fully qualified to write it, having taught electrical engineering at Stanford since 1925; Dr. Terman was Stanford's Dean of Engineering for ten years beginning in 1945 and Vice President of the University from 1958 until retirement in 1965.

IV
Architecture

With the Alumni

Michael P. Buckley, M.A.R. '72, is President of Halcyon Ltd. He was one of the principal architects in Halcyon's development of the mall in the Hartford Civic Center and is currently development director for a commercial development in Citicorp's office tower under development in New York . . . **Francis Bulbulian,** M.A.R. '68, is design coordinator at Ellerbe Architects — masterplanning two self-sufficient medical communities for the Ministry of Defense and Aviation of Saudi Arabia . . . **Burton Goldberg,** M.C.P. '60, has been working as an associate director of Public Affairs Counseling, a division of Real Estate Research Corporation located in San Francisco, Calif.

Benjamin Franklin Smith III, M.Arch. '68, is beginning his second year as Assistant Dean of the School of Architecture at Tulane University.

V
Chemistry

With the Alumni

Barry M. Trost, Ph.D. '65, Professor of Chemistry at the University of Wisconsin, Madison, is the 1977 winner of the American Chemical Society's $2,000 Award in Pure Chemistry — recognition for his research and synthesis of complex organic molecules, particularly hormones that control the development and behavior of insects . . . **John T. Viola,** Ph.D. '67, earned the U.S. Air Force Outstanding Unit Award. Major Viola is a research and development management officer with the Air Force Systems Command's Office of Scientific Research, Bolling A.F.B., Washington, D.C. . . . **Forrest A. Richey,** Ph.D. '68, has been promoted to Project Scientist in the Research and Development Department at the Union Carbide Technical Center, South Charleston, W. Va. . . . **Thomas M. Bare,** Ph.D. '69, has joined the biomedical research department of ICI United States Inc. as a research chemist in the medicinal chemistry section . . . **Michael C. Chen,** Ph.D. '73, now works in the Plastics Technology Division at Baytown Research and Development Center of Exxon Chemical Co., Baytown, Tex.

VI
Electrical Engineering

Mark A. Orenstein

Robert Spinrad

With the Alumni

Robert Spinrad, Ph.D. '63, has been appointed Vice President of the Systems Development Division in the Information Technology Group of Xerox Corp., El Segundo, Calif. . . . **David E. Acker,** S.M. '65, has been elected Vice President of Andersen Laboratories of Hartford, Conn.; he is also Vice President of Television Microtime, a subsidiary of Anderson Laboratories . . . **Mark A. Orenstein,** S.M. '68, has been appointed Assistant Director in the Data Processing Department at The Travelers Insurance Co., Hartford, Conn. . . . **Robert N. Smith,** S.M. '45, was nominated by President Ford for the position of Assistant Secretary of Defense for Health and Environment; he will oversee and coordinate medical and dental programs in the army, navy and air force departments . . . **Richard N. Spann,** '61, has joined AD-AGE, INC., of Boston, specialists in computer graphics products, as Vice President of Development.

Garry Meyer, S.M. '72, is studying for his doctorate in sociology at the State University of New York at Stony Brook; he is also Assistant Manager of the computing center at S.U.N.Y. . . . **Peter Jessel,** Ph.D. '72, is on leave from the University of Pennsylvania and has returned to work at the Laboratory for Computer Science at M.I.T. . . . **Robert Piankian,** S.M. '72, is a lecturer in electrical engineering at M.I.T., a senior engineer at Massachusetts General Hospital, and runs a consulting firm — Piankian Engineering.

Jack Capon, S.M. '55, Staff Member at M.I.T.'s Lincoln Laboratory, spoke at a fall meeting of the Boston section of the I.E.E.E. about his current research on computer programs simulating a Microwave Landing System (MLS) — to determine obstacles to the use of MLS in typical airport environments . . . "Progress in Controlled Fusion" was the subject of **Ronald R. Parker,** Sc.D. '63, Director of the Alcator project at the M.I.T. Francis Bitter National Magnet Laboratory, at a fall meeting of the Magnetics, Power Engineering and Nuclear and Plasma Sciences Chapters . . . **Daniel U. Wilde,** Ph.D. '66, professor of business at the University of Connecticut, is Director of the New England Research Application Center, the largest university-operated data bank in the world.

Narendra P. Loomba, S.M. '54, who teaches in the Department of Management at Baruch College of C.U.N.Y., is the author of two books published in 1976: *Linear Programming — Managerial Perspective,* and (with E. Turban) *Readings in Management Science.*

VII
Life Sciences

With the Alumni

Barry J. Fry, Ph.D. '70, has been named Senior Vice President of KPR Infor/Media Corp., of New York City, and a member of the company's Board of Directors . . . **Joel L. Sussman,** Ph.D. '72, will spend the year at the Weizman Institute in Rehovot, Israel. . . . **Joan V. Ruderman,** Ph.D. '74, a postdoctoral fellow in the Department of Biology at M.I.T., has been selected a 1975-1976 NATO Postdoctoral Fellow for study abroad. She plans research in molecular biology at the University of Zurich in Switzerland.

VIII
Physics

Professor Ali Javan delivered the 1975 Frederic Ives Medal address at the 1976 meeting of the Optical Society of America in October. His subject: "Precise Interferometric Laser-Wavelength Measurements: A Progress Report."

With the Alumni

Thomas B. Lewis, Ph.D. '65, is New Product Development Manager at Monsanto's Rubber Chemicals marketing and research facility in Akron, Ohio. He and his wife, Mary, and their three children live in Shaker Heights . . . **La Ru Barker Lynch,** '41, was a Democratic candidate for representative to the state legislature from Exeter, N.H. . . . **David W. Berger,** S.M. '56, is Manager of Internation Program Management at The Babcock & Wilson Co., Lynchburg, Va. . . . **T. Marshall Hahn, Jr.,** Ph.D. '50, Executive Vice President for Pulp, Paper, and Chemicals of Georgia-Pacific Corp., is now also President of Georgia-Pacific . . . **Albert H. Teich,** '64, As-

After 45 years at Geophysical Services, Inc., and Texas Instruments, Inc., Cecil E. Green, '23, has moved from "active" retirement to "semi-active" retirement — a way of saying that he is now Honorary Director instead of Director of Texas Instruments, Inc. To mark the change, old friends gathered at the Dallas Petroleum Club to give Cecil some mementos — a book on seismic reflection techniques, a log of the *M/V Cecil H. Green's* ten years at sea for G.S.I., a wood-mounted mosaic of the G.S.I. logo, and a collage (at left) tracing Cecil's role in G.S.I. Erik Jonsson, a co-founder of G.S.I. and T.I. (left in the photo), said Cecil once accused him of hiring "some outrageous people" and thereupon took over (temporarily) the personnel job himself. Others called Cecil "an old smoothie," "a real operator," "an idea man with vision and determination," "a 'doodlebugger' most of us will never forget." Frank Lord, Editor of T.I.'s *Grapevine*, wrote, "One couldn't help but feel the distinctive atmosphere . . . genuine love and deep respect . . . that surround this man . . ."

sociate Professor of Public Affairs at George Washington University, has been studying the politics and administration of large research and development laboratories in the government sector.

Robert C. Schaller, S.M. '70, now has his Ph.D. in physics from the University of Denver. . . . **Carl S. Schneider,** Ph.D. '67, has been promoted to Associate Professor of Physics at the U.S. Naval Academy.

IX
Psychology

Ann M. Graybiel, Ph.D. '71, Assistant Professor of Psychology and Brain Science since 1973 has been promoted to Associate Professor.

With the Alumni

After doing postdoctoral work at the National Zoological Park, **Michael Murphy,** Ph.D. '72, is now at the National Institutes of Mental Health where he does research in neuroethology.

X
Chemical Engineering

With the Alumni

Robert E. Fisher, Sc.D. '66, has been appointed director of the specialty chemicals process design and economics division at Amoco Research Center in Naperville, Ill. . . . **William A. Reed,** S.M. '43, is director of technical development for Republic Steel Corp. . . . **Arthur B. Metzner,** Sc. D. '51, H. Fletcher Brown Professor and Chairperson of the Department of Chemical Engineering at the University of Delaware, has been appointed a member of the Corporation visiting committee of the Department of Chemical Engineering at M.I.T. . . . **William Eykamp,** Ph.D. '65, has been elected a corporate member of Morgan Memorial Goodwill Industries of Boston. Mr. Eykamp is vice president and general manager of the Operations Division of Abcor, Inc., a chemical equipment company located in Cambridge, Mass.

Anthony C. Yeung, S.M. '73, is special projects manager for corporate engineering for Travenol Laboratories . . . **William C. Behrmann, Jr.,** Sc.D. '60, has been promoted to Senior Engineering Associate at the Exxon Research and Development Laboratories at Baton Rouge, La. . . . **Richard D. Hoyt,** S.M. '57, is Director of Capital Budgets of ACF Industries, Inc. . . . **David T. Hayhurst,** S.M. '73, received his doctorate from Worcester Polytechnic Institute last May and is an assistant professor in the Department of Chemical Engineering at Cleveland State University.

XI
Urban Studies

Michael H. O'Hare, Gary A. Hack, and **Joseph Ferreira, Jr.,** '67, have been promoted from Assistant to Associate Professor. Professor O'Hare has been working on research programs involving government policy toward the arts and environment, including solar energy and urban design; Professor Hack joined the faculty in 1971 and headed the Environmental Design Program from 1972-1975; and Professor Ferreira is involved in research related to risk management through government programs and regulations — especially in regard to casualty and liability insurance, auto accidents and emergency services — and evaluating federal subsidy programs.

With the Alumni

Devere Wellington Ryckman, Sc.D. '56, has been included in the Marquis 39th Edition of *Who's Who in America.* He is founder and president of D.W. Ryckman & Associates, Inc., and recognized as an international authority on environmental science and engineering . . . **B. J. Steigerwald,** S.M. '56, Environmental Protection Agency Deputy Assistant Administrator, was chosen Federal Environmental Engineer of the Year by the Conference of Federal Environmental Engineers. . . . **Alonzo Wm. Lawrence,** S.M. '60, has been appointed Vice President for Koppers Co., Inc., of Pittsburgh . . . **Richard S. Howe,** S.M. '61, is Director of the Division of Environmental Studies at The University of Texas at San Antonio.

Barbara B. Katz, M.C.P. '75, has been appointed Community Relations Associate of the Jewish Community Council of Metropolitan Boston . . . **Joan Moskowitz,** M.C.P. '73, was appointed by Gov. Michael Dukakis to the Massachusetts Board of Approval and Certification of Physician Assistant Programs.

XII
Earth and Planetary Science

With the Alumni

Edward A. Boyle, Ph.D. '76, was selected as a 1975-1976 NATO Post-doctoral Fellow for study abroad; he will work in marine geo-chemistry at the University of Edinburgh . . . **Susan Nygard,** S.M. '75, studied at Michigan State University concentrating in geology and is now working for Seismograph Services Corp. in Alma, Mich. In August, 1975, she married Ed Kronenberger who graduated from M.I.T. in 1974 in chemical engineering.

Genetics and Cell Biology

A $12,000 grant from the Greater Boston Chapter of the National Genetics Foundation will be used for new equipment for separating proteins and mutant cells and for studying the process of oxygen utilization by cells, according to Dr. Salvador E. Luria, Director of the Center for Cancer Research.

The equipment will make possible research on the genetic implications of two physiological processes:

— How oxygen derived from respiration in cells is converted into usable chemical energy.

— How a certain single genetic mutation halts protein synthesis and renders cellular proteins unstable at high temperatures.

A. Edward Allinson

F. Hudnall Christopher, Jr.

Lewis G. Pringle

Richard A. Jacobs

XIII
Ocean Engineering

With the Alumni

Henry J. Nardone, N.E. '52, is Acting Manager of the Quonset Point facility of General Dynamics' Electric Boat Division in Westerly, R.I. . . . **John F. Wing,** '55, a vice president of Booz, Allen & Hamilton, Inc., has been appointed Director of their new Transportation Consulting Division's federal transportation consulting work and will direct the expansion of the division's rail consulting practice. He will also continue consulting on major transportation technology and maritime projects. . . . Lieutenant **Robert A. Baeder,** S.M. '71, has completed the Basic Officer Course at the Naval Submarine School in Groton, Conn.

An advocate of the use of wind power as a viable source of energy is **William Edward Heronemus,** S.M. '48, in his article, "Wind Power: A Significant Solar Energy Source," published in the August issue of *Chemtech.* Now Professor and Associate Head of Civil Engineering at the University of Massachusetts, William Heronemus, a retired Captain from the U.S. Navy, has also written on the subjects of sea-going engineering and solar power.

Commander **William A. Kerr, Jr.,** N.E. '67, recently completed a tour of duty as Chief Engineer for the aircraft carrier *U.S.S. Midway.* In addition to the professional stimulation of operating and maintaining an aircraft carrier homeported overseas, there was the opportunity for Bill and his family to live in Japan for two years. He is now assigned to the Commander, Naval Air Force, U.S. Pacific Fleet, as the Chief Engineer.

XIV
Economics

With the Alumni

Charles Levenstein, Ph.D. '66, has left a teaching position at Lehman College of the City University of New York to be assistant professor of economics at the University of Connecticut; he specializes in the subject of urban migration . . . **Norman Gibson,** Ph.D. '74, was appointed Assistant General Manager for Dominion Bank and will be living in Singapore from three to five years . . . **Glenn T. Hammons,** S.M. '71, graduated from medical school at Washington University in St. Louis last spring and then began a laboratory medicine residency in clinical pathology at Barnes Hospital . . . **David B. Lipsky,** Ph.D. '65, is Visiting Associate Professor of Industrial Relations at the Sloan School, on leave from Cornell University.

William H. Gruber, Ph.D. '65, a lecturer at the Sloan School and President of the Research and Planning Institute, Inc., a management consulting firm in West Newton, Mass., is the co-author of the book *The New Management: Line Executive and Staff Professional in the Future Firm,* recently published by McGraw-Hill. . . . **John M. Marshall,** Ph.D. '69, has been promoted to Associate Professor of Economics at the University of California, Santa Barbara.

XV
Management

With the Alumni

Henry F. Frailey, S.M. '57, a vice president of Corning Glass Works, has been appointed business manager of television products . . . **Donald E. McGuire,** '50, is now manager of manufacturing in the Electrical Products Division of Corning Glass Works . . . **Thomas R. Williams,** S.M. '54, Chief Executive Officer of The First National Bank of Atlanta, was elected Chairman of the Board . . . **F. Hudnall Christopher, Jr.,** S.M. '59, is now vice president of allied products and services of R. J. Reynolds Tobacco Co. . . . **Carroll G. Tompson,** S.M. '69, a vice president of the R. J. Reynolds Tobacco Co., has been elected president and chief executive officer of RJR Archer, Inc., manufacturers of packaging materials.

The new director of manufacturing and engineering planning in the Manufacturing and Engineering Division of Corning Glass Works is **Gillett Welles III,** S.M. '63 . . . **James C. Emery,** Ph.D. '54, was elected President of EDUCOM, a consortium of universities and non-profit organizations founded to help its members make effective use of computers and communications technology . . . **Lewis G. Pringle,** Ph.D. '69, has been appointed Director of Management Information Services and International Research at Batten, Barton, Durstine and Osborn, Inc.; he will also continue in his position as a vice president of their advertising agency . . . **Lewis A. Phillips,** S.M. '68, is Plant Manager of the Georgia-Pacific corrugated plant in Olympia, Wash.

Gary L. Bergstrom, Ph.D. '68, is vice president of Putnam International Advisory Co. S.A. He is also vice president and head of the computer investment research department of The Putnam Management Co., Inc. . . . **J. Phillip Samper,** S.M. '73, is Assistant to the General Manager of the Marketing Division for the U.S. and Canadian Photographic Division of Eastman Kodak . . . **Richard A. Jacobs,** '56, has been elected a vice president of A. T. Kearney, Inc. . . . **Alexis Falquier,** S.M. '67, has been elected a partner in McKinsey Co. and is involved in developing their practice in Mexico . . . **Byron Miller,** S.M. '72, joined A. T. Kearney as an associate in June.

Robert Cann, S.M. '72, has also received his master's degree in electrical engineering and is listed in *Who's Who in Black America.* . . . **Arthur Gerstenfeld,** S.M. '66, who is associated with the Schools of Management and Engineering at Boston University, recently published a study of research and development projects in West Germany in the I.E.E.E. Transaction of Engineering Management . . . **Mark S. Plovnick,** S.M. '70, is

J. Phillip Samper

Carroll G. Tompson

John J. Wetzel II

L. Banks

Assistant Professor of Management at Clark University . . . **A. Edward Allinson,** S.M. '71, has been elected Vice President of State Street Bank Financial Corp. and State Street Bank and Trust Co. . . . **John J. Wetzel II,** S.M. '73, is staff engineer of engine emissions systems in Pontiac Motor Division's product engineering department.

James Kidney, S.M. '61, is lecturing at the School of Accounting and Business Administration at the University of Singapore . . . **William Kay,** S.M. '63, is Executive Vice President of Sun Company, Inc. with responsibilities for subsidiary companies engaged in refining, marketing, research and development, and information systems . . . **Victor R. Macdonald,** S.M. '68, an IBM communications operations director, was appointed to the Board of Education in New Canaan, Conn.

XVI
Aeronautics and Astronautics

Charles Stark Draper, '26, is "a man of enormous achievement . . . the father of inertial guidance," says the citation for his induction as a charter member of the new International Space Hall of Fame at Alamogordo, N.Mex., last October 5. Dr. Draper, who graduated from M.I.T. in the Class of 1926 and went on to head its Department of Aeronautics and Astronautics and to found its Instrumentation Laboratory which is now renamed in his honor, was one of eight Americans (three still living) in a total of 35 initial inductees. Among other famous names in the roster were Wernher F. von Braun, Robert H. Goddard, Hugh L. Dryden, and Yuri Gagarin.

With the Alumni

Arthur Gelb, Sc.D. '61, founder and president of the research and development firm Analytic Science Corp., of Reading, Mass., has been appointed to the Massachusetts Port Authority Board of Directors . . . **Dinesh Gupta,** S.M. '70, is working on the development of biomedical systems in a Nashua, N.H., based company and attending Northeastern Evening School in engineering management . . . **David Kohlman,** Ph.D. '63, is Visiting Professor of Aeronautics at the U.S. Air Force Academy, on leave from the University of Kansas . . . Lieutenant Colonel **Terry R. Jorris,** S.M. '63, completed the Air Force Air War College military education course at Maxwell Air Force Base, Alabama, last year. Terry works at Andrews Air Force Base, Maryland; and his wife, the former Marlene L. Hiller, '64, works at Washington Hospital Center.

Donald E. Hickman, S.M. '68, Captain in the U.S. Air Force and Developmental Astronautical Engineering Officer at Hickam Air Force Base, Hawaii, has received his second award of the U.S. Air Force Commendation Medal . . . First Lieutenant **John E. Keesee,** S.M. '75, a research engineering officer at the F. J. Seiler Research Laboratory, is now at the U.S. Air Force Academy . . . **A. T. Yu,** S.M. '46, is President of ORBA Corp., a firm specializing in all aspects of bulk material handling and transportation systems located in Fairfield, N.J. ORBA Corp. recently dedicated the Superior Midwest Energy Terminal in Superior, Wis. — the first major coal terminal constructed in a metropolitan area of the U.S. under current environmental regulations. . . . **Robert C. Seamans, Jr.,** S.M. '42, was the principal speaker and one of four honorary degree recipients at the 98th Founder's Day Exercise at Lehigh University. . . . **Marshall H. Kaplan,** S.M. '62, Associate Professor of Aerospace Engineering at Penn State University, is the author of the graduate text *Modern Spacecraft Dynamics and Control* published by John Wiley & Sons, Inc.

XVII
Political Science

Robert I. Rotberg, Professor of History and Political Science at M.I.T., is co-editor of *The African Diaspora*, a collection of original essays which describe the ways in which Africans left their homelands, became exiles, and adapted to their new environments — recently published by Harvard University Press.

With the Alumni

David L. Rosenbloom, Ph.D. '70, has been appointed Commissioner of Boston's Health and Hospitals Department . . . **Herbert D. Friedman,** Ph.D. '68, is Chairman of the newly-created Committee on Mental Health of the Massachusetts Bar Association; he is also an associate in the Boston firm of Mahoney, Hawkes and Goldings . . . **William Platte,** Ph.D. '71, Captain in the U.S. Navy, turned over command of the U.S. Naval Air Facility in Sigonella, Sicily, in September and is now Deputy and Chief of Staff of the Naval War College in Newport, R.I. . . . **James Jonah,** Ph.D. '67, is with the United Nations in the Office of the Under-Secretaries-General for Special Political Affairs. . . . **Robert B. Saba,** S.M. '61, assumed the position of Vice President of Plant Facilities in the Metals Industries Group of the Pullman Swindell division of Pullman Inc., of Pittsburgh, in November.

XVIII
Mathematics

Three members of the faculty have been promoted from Assistant Associate Professor: **Norberto L. M. Kerzman, Eugene M. Kleinberg,** '67, and **James W-K Mark.**

With the Alumni

Zdzislaw A. Melzak, Ph.D. '56, Professor of Mathematics at the University of British Columbia, has just published the second volume of *Companion to Concrete Mathematics: Mathematical Ideas, Modeling and Applications.*

An Adjunct Professor in Business and Society

Louis Banks, who was Editor of *Fortune* from 1965 to 1970 and then for three years Editorial Director of Time, Inc., supervising editorial work on all Time publications, is now Adjunct Professor of Management at M.I.T. He's teaching Sloan School subjects in Business and Social Pressures and Business and the Media.

Since retiring from Time, Inc., in 1973 Professor Banks has been teaching at Harvard Business School; throughout his career he's concentrated on business policy and the relationships between business and society.

Professor Banks studied at the University of California (Los Angeles), and he joined *Time* magazine's Los Angeles bureau upon returning from World War II service in the Navy. His first post at *Fortune* was Assistant Managing Editor in 1961.

"The Most Conservative Democrat Since 1924"

Last fall's election was "class-stratified," says Walter Dean Burnham, Professor of Political Science. Jimmy Carter owes his victory to his support by the "have lesses," while President Ford was supported by the "haves." Carter's victory was narrow because "the 'have-nots' did not vote," Professor Burnham told an M.I.T. seminar in mid-November. Indeed, it was touch-and-go: "If it had rained in New York City on Election Day, Gerald Ford would still be President," said Professor Burnham.

Professor Burnham considered Carter "the most conservative Democratic candidate since 1924. He was to right of the platform, and this helped him win the election." Now, in the White House, Carter's job is to make the transition between "the politics of support" — which he used to gain office — and the "politics of power" — which he must use to govern effectively.

M. Halle

Linguistics Joins Philosophy in a New Department

How people talk and write is an important clue to how they think.

Hence the growing affinity of the disciplines of philosophy and linguistics at M.I.T., where in the 1960s and 1970s there have been significant developments in analyzing language structure and its acquisition.

Now the marriage has been consummated: effective this fall, a new Department of Linguistics and Philosophy brings together the Institute's work in linguistics and philosophy; programs in foreign languages and their literatures have become part of the Department of Humanities, and the Department of Foreign Literatures and Linguistics has been eliminated as an administrative entity.

Morris Halle, formerly Acting Head of the Department of Foreign Literatures and Linguistics, has become Acting Head of the new Department of Linguistics and Philosophy, and he has begun teaching a new undergraduate Course leading to the S.B. degree in "Language and Mind." (The traditional undergraduate program in "Philosophy" continues.)

The central focus of the new undergraduate program — an overlapping of philosophy, linguistics, and cognitive psychology — is the nature of language and of mental representation of knowledge, the nature of linguistic knowledge, and the innate basis for the acquisition of such knowledge. Professor Ned Block, who is in charge of the new undergraduate program, thinks it is the first in this field to be given in the U.S. "There is a growing interest in this new field," Professor Block told *The Tech*, "and many M.I.T. students are very excited about it."

In addition to being named Acting Head of the new Department, Professor Halle has become Ferrari P. Ward Professor of Modern Languages and Linguistics; he succeeds in that Chair — it is the result of a bequest by the late Mr. Ward ('26) — Professor Noam A. Chomsky, named Institute Professor last spring. Professor Halle has been in charge of the Institute's linguistics program ever since its beginning — "virtually its 'department head,'" said Harold J. Hanham, Dean of the School of Humanities and Social Science.

XIX
Meteorology

Ronald G. Prinn, Sc.D. '71, a specialist in planetary atmospheres and their evolution, has been promoted from Assistant to Associate Professor.

With the Alumni

Henry W. Brandli, S.M. '65, retired from the United States Air Force in July as a Lieutenant Colonel and as of November began working for Environmental Research and Technology, Inc., of Concord, Mass., as a Research and Operational Satellite Meteorologist. The United States Air Force is publishing his book *Satellite Meteorology* and he recently co-authored a chapter in the *Manuel of Remote Sensing*, published by the American Society of Photogrammetry. . . . **Darryl W. Copeland,** '59, was promoted from Executive Vice President to President of Cole-Layer-Trumble Co., a subsidiary of Day & Zimmerman, the Philadelphia-based international engineering, construction, management and consulting firm . . . Lieutenant Colonel **Ronald L. Lininger,** S.M. '52, was awarded the Meritorious Service Medal of the United States Air Force for superior performance as an advanced weather officer to Scott Air Force Base, Illinois; he is presently assigned to Kapaun Barracks, Germany, with a unit of the Air Weather Service.

XX
Nutrition and Food Science

Three members of the Department have been promoted from Assistant to Associate Professor: **Michael C. Archer** (carcinogenesis, enzymology, and bioanalytical chemistry), **James M. Flink,** '64, (food processing and novel protein sources), and **Loy D. Lytle** (neural effects of dietary variations).

With the Alumni

Arthur W. Phillips, Jr., Sc.D. '47, has been Professor of Microbiology at Syracuse University in the Department of Biology since 1959 . . . **William J. Goldman,** S.M. '64, graduated last year from Hahnemann Medical College and Hospital and will complete an internal medicine residency at Pennsylvania Hospital of the University of Pennsylvania . . . **Ronald C. Wornick,** S.M. '60, Group Vice President of Food Service Industries of Clorox Co., is President of the International Food Service Manufacturers Association and Chairman of the National Alliance of Businessmen in Oakland, Calif. . . . **Shirley M. Picardi,** Ph.D. '76, has been appointed Industrial Liaison Officer at M.I.T. . . . **John H. Litchfield,** '50, is Manager of Bioengineering and Health Sciences Research at Battella Columbus Laboratories . . . **John W. Zahradnik,** Ph.D. '65, is Chairman of the combined Departments of Agricultural Mechanics and Bio-Resource Engineering at the University of British Columbia in Vancouver, Canada. . . . **William P. Steffee,** Ph.D. '74, has started a practice in clinical nutrition — Medical Nutrition Associates, Inc., a referral service for physicians located in Wellesley, Mass.

XXI
Humanities and Social Science

Elting Elmore Morison, Elizabeth and James Killian Class of 1926 Professor, Emeritus, and his wife, Elizabeth Forbes Morison, co-authored *New Hampshire: A Bicentennial History*, the latest volume in the States and the Nation series being published by W. W. Norton & Co.

Wilma E. Wetterstrom, formerly Instructor, is now Assistant Professor of Anthropology and Archaeology; a graduate of the University of Michigan, she's been at M.I.T. since 1974.

Three appointments as Visiting Assistant Professors were announced late last fall:

Sheldon H. Davis, Director of the Anthropology Resource Center in Cambridge, is teaching part-time at M.I.T.; he's a specialist in social anthropology.

Joseph H. Hall, who is a Ph.D. candidate in American civilization at the University of Pennsylvania, is full-time Visiting Assistant Professor. He is Instructor in Anthropology and Archeology at Germantown Academy, Germantown, Penn.

Barry Lydgate, Assistant Professor of French at Wellesley College, is part-time Visiting Assistant Professor at M.I.T.

Marcus A. Thompson has been promoted to Associate Professor. Professor Thompson is widely regarded as one of the brilliant violists of his generation and since he joined the M.I.T. faculty in 1973 has made frequent tours and recitals. He founded the M.I.T. Chamber Music Society and directs the M.I.T. Chamber Players.

With the Alumni

Don M. Shakow, '62, is Assistant Professor of Economics at Clark University; his research has been in the economics of labor-managed enterprises and systems, and in cooperative business organization.

XXII
Nuclear Engineering

Louis S. Scaturro received his Ph.D. from Columbia University at the end of the summer with a thesis in the field of experimental plasma physics, and he has now joined the Department as Assistant Professor. He's in charge of 22.07 — "Preparation for Plasma Physics," the introductory course in fusion processes given primarily for sophomores.

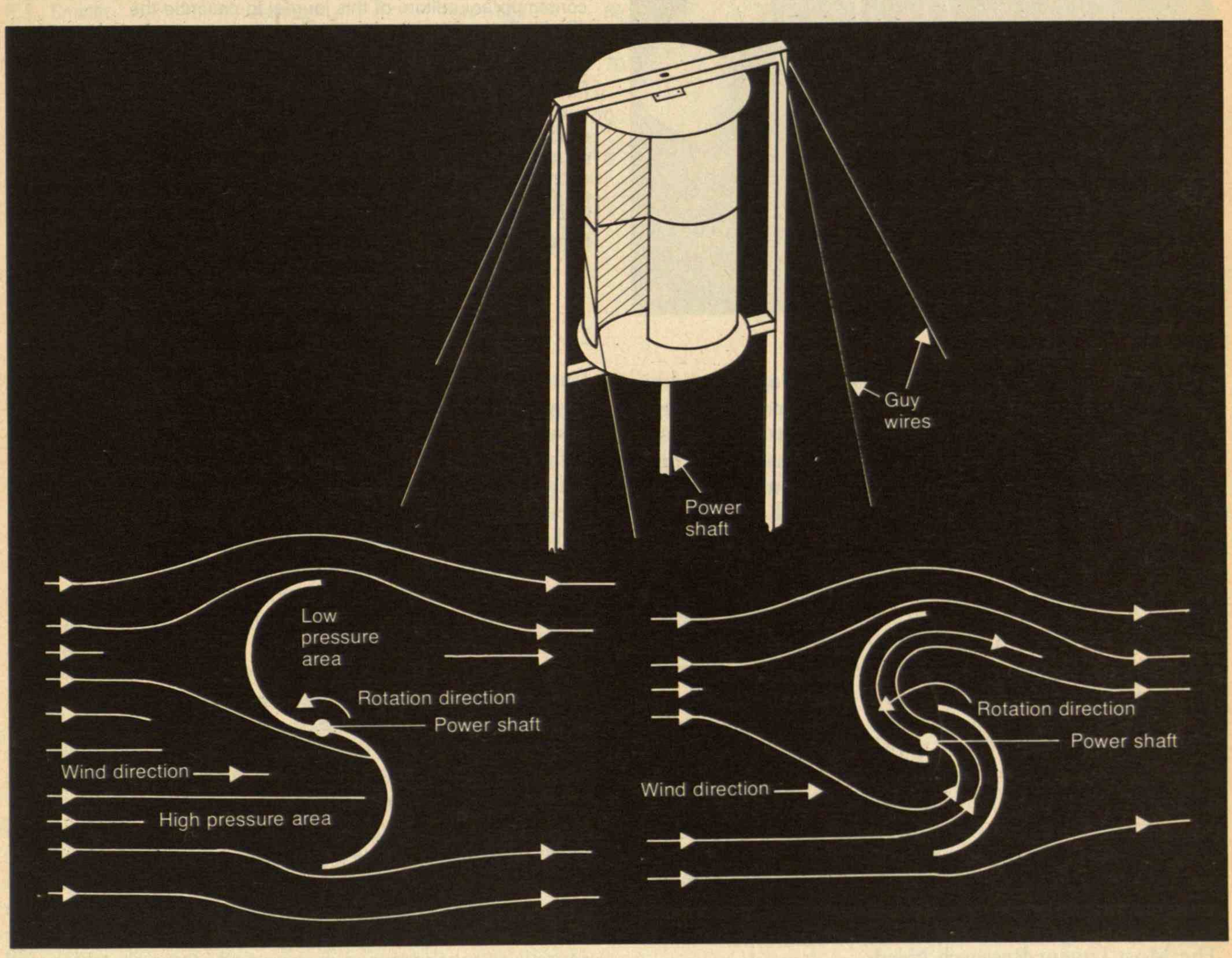
With the Alumni

Allan A. Offenberger, Ph.D. '68, has returned from a sabbatical year at the Culham Research Laboratory of the U.K. Atomic Energy Agency, Abingdon, Oxforshire, to a promotion: Professor of Electrical Engineering at the University of Alberta.

Glenn E. Lucas, S.M. '75, has been awarded the Joseph Warren Barker Fellowship in Engineering for 1976 . . . **George Odette,** Ph.D. '71, has been promoted to Associate Professor of Nuclear Engineering at the University of California at Santa Barbara . . . **Andrew Kadak,** S.M. '72, is Director of Nuclear Information for the New England Electrical Systems; he lives with his wife and two children in Barrington, R.I. . . . **Eric Westberg,** S.M. '72, is working as construction area coordinator and living at the construction site of Brazil's first nuclear power reactor in Angra dos Reis, approximately 100 miles down the coast from Rio de Janeiro. With him are his wife, Lucia, and their two children; classmates in the area can contact them through the Westinghouse office in Rio de Janeiro.

James L. Klucar, S.M. '69, is Vice President of Engineering for Signal Hill Electric, Inc., of Mountain View, Calif. . . . **Richard Weader,** Nu.E. '67, is employed by Nuclear Energy Services, Inc., a division of Automation Industries, Inc., as a nuclear engineer. He and his wife, Amy, have a son, James, born in March, 1976 . . . **Martin L. Bowling, Jr.,** Nu.E. '71, has been appointed Supervisor of Nuclear Fuel Engineering in the Fuel Resources Department of Virginia Electric and Power Co., Richmond.

A widely used type of vertical-axis windmill is the Savonius rotor. The torque output (or rotational speed) of the rotor can be controlled by a simple adjustment of air flow at one point. The geometry consists of a cylindrical shell, split in half and mounted to rotate between circular top and bottom plates. The two halves of the shell are separable so that the "wing passage" between them can be opened and closed. With the passage closed (left), circulation is impeded and there exists a partial vacuum on the downwind side of the wing which is advancing into the wind; there is a large retarding force on this wing and the net torque on the rotor is only moderate. With the "wing passage" open (right), the region of vacuum is replaced by a region of pressure and torque output is increased by a factor of three or more. Savonius rotors are usually constructed with fixed geometry, the wing passage being adjusted for maximum output. This occurs when the distance between centers of the two semicircles is about half a diameter.



system. When the wind disappeared this accumulated water was used to generate power. Gas turbines and diesel engines are suitable standby sources for large or small systems.

Substantial fuel savings could be realized by a large wind generator placed in a windy location in parallel with a generator powered by a diesel engine or oil-fired gas turbine. Such an oil-fired machine consumes about two barrels of fuel per 1,000 kilowatt-hours of electricity generated. On a good site, a 100-kilowatt wind turbine will produce 300,000 kilowatt-hours per year, saving 600 barrels of diesel fuel, $6,000 to $12,000 a year. If a battery of ten such wind generators could be purchased and installed for $500,000 — perhaps plausible prices for production models — the ten would pay for themselves in seven years without any allowance for year-to-year increases in fuel cost. If fuel prices continue to increase, the wind generator will look even more favorable.

Four types of applications where wind energy may have a place in the near future are:

□ Water pumping in small volumes with medium and high lifts for livestock, people, and minor irrigation in sparsely populated, dry areas — a traditional application, and commercially-built multivane fans are now in use.

" . . . a Gargantuan wind turbine" . . . "such a windmill as Don Quixote never would have tilted . . ." are among phrases used by contemporary editors of this journal to describe the "Smith-Putnam" generator on Grandpa's Knob, a windy height in southern Vermont (left). Completed early in the 1940s, it was in fact the largest wind system ever built — blades over 80 feet long having a chord of over 11 feet (above), mounted on a 110-foot tower, designed to produce 1,000 kilowatts of power in a 30-m.p.h. wind. A blade failure at the point of a known metallurgical fault caused destruction of the machine in 1945, and subsequent economic studies led to abandonment of the project. But prior to failure, the unit had frequently pumped its full capacity of power into the southern Vermont electric grid. (Photos: John B. Wilbur from M.I.T. Historical Collections)

☐ Water pumping in large volumes, with low or medium lifts, for irrigating cereal grains or other crops. High-efficiency wind turbines making electricity to drive pumps of one to five kilowatts capacity are available now, though not at acceptable cost. Many agricultural regions are unsuitable because of insufficient wind, but some regions are suitable.

☐ Battery chargers for low-power, high-value communications and illumination energy in remote locations. Above 20 or 30 watts, a small wind generator is likely to be a more economical choice than a photovoltaic panel, depending, of course, on the wind. The equipment for this application is available now.

☐ Supplementary energy sources for centralized power grids. Large propeller-type (horizontal-axis) or Darrius wind machines generating 100 kilowatts or more would be required. This is not new technology, but there is room for improvement and cost reduction through mass production. The centralized power grids will find the energy from wind to be economical if they have an alternative source with a short response time in the system.

The Most Urgent Research Needs

Many important and worthwhile research programs have been started in the last few years since funds from the National Science Foundation and the Energy Research and Development Agency became available. It is not my purpose to review these here. I will speak only of two rather simple and yet rather urgent requirements. One concerns the wind and one concerns the machines.

A high priority for power windmills — and one on which work is likely to be cost-effective — is a systematic search for good sites. This would be facilitated by more appropriate instruments. Present instruments are too expensive because they give too much information. Consequently only a few locations can be instrumented. Knowledge of wind below 10 m.p.h. is unimportant for power windmills, and so is wind direction. Present instruments give a complete record of wind velocity and direction at all moments of time. What is needed is an integrated record of the energy in winds over 15 m.p.h., or even just mean windspeed.

The search for good sites would be facilitated greatly by a change in the manner of its organization. The present approach is to rely on an organized bureaucracy, a national meteorological service. This is good for archiving data and for methodological wind survey programs, but it does not encourage "prospecting" — the search for the scattered, barely predictable excellent sites. The U.S. government once sponsored an individual reward program to encourage prospectors for domestic uranium ores; the same kind of program would be useful in the search for wind power sites.

In power generating windmills of large size the index of merit is output per unit capital cost (*not* efficiency). There are two approaches to improving this. One approach is to improve aerodynamic and electrical design to extract a higher proportion of the power in the wind. The other route is to work toward designs and materials which will make the finished machines less costly. The most sophisticated horizontal-axis wind turbines already extract more than half the power in the wind (at the most favorable windspeed), only a few points below the absolute upper limit of 59.3 per cent. However, the problem of reducing cost through engineering has hardly been approached as yet, because no national program has ever progressed beyond the point of testing a few prototypes.

The history of multivane fan water pumping windmills demonstrates that product improvement with the incentive of sales competition in a volume market can bring wind machines to large-scale utilization. If a volume market for power generating windmills could be provided

	Location	Dates	Rated power (kilowatts)	Rated wind speed (m.p.h.)	Diameter of swept circle (feet)	Number of blades	Rated rotation speed (r.p.m.)
Smith-Putnam	Grandpa's Knob, Vermont	1941-45	1,250	32	175	2	29
Aerowatt	60 km. west of Paris	1957-65	800	45	105	3	47
NEYRPIC	France	1963-64	1,000		115	3	
NEYRPIC	France	1960-63	132		69	3	
Balaclava	U.S.S.R.	1931-41	100	25	98	3	30
Gedser	Denmark	1957-67	200	33	79	3	30
John Brown	Orkney, U.K.	1950s	100	35	50	3	130
N.A.S.A./E.R.D.A.	Sandusky, Ohio	1975 —	100	18	124	2	40
F. L. Smidth (12 units)	Denmark	1941-50s	60	22	57	2	variable
F. L. Smidth (6 units)	Denmark	1943-50s	70	19	79	3	variable
Isle of Man	U.K.	1958-?	100	41	50	3	75

This chart summarizing the characteristics of some large wind generators reveals that only two such machines have been built in the U.S., and the number of units elsewhere in the world can be counted on the fingers of two hands. The largest of all was the ill-fated Smith-Putnam machine, which was connected briefly into the New England power grid in 1945. A 200-kilowatt generator will soon be completed on the Magdalen Islands, Canada, to supply power for those isolated communities.

in the U.S., manufacturers would have some incentive for investing in tooling and design improvements in order to cut costs. Possibly a subsidy to purchasers which would have the effect of artificially lowering the cost of windpower at the start would be an effective way to spend government funds. At present, available funds are used to support the building of prototypes, accepting very high unit costs in the hope of gaining knowledge and thus improvements in performance. The approach resembles that used in aerospace and defense development; it may not be the best way to develop wind energy.

Prospects for Wind Power on a Large Scale

With respect to large-scale wind power development for electricity production, the largest single problem today is that almost no one takes the possibility seriously. Most people do not believe wind energy can ever make an important contribution to U.S. energy needs. Various E.R.D.A.-commissioned studies have concluded otherwise. Assuming cost-effectiveness, what can be said about the prospects?

A well-engineered wind generator of conventional type (two blade propeller) properly matched to its site can be expected to have a capacity factor of 35 to 40 per cent — i.e., in one year a unit rated at 1,000 kilowatts (1 megawatt) can be expected to deliver 3,000 to 3,500 megawatt-hours. Assuming that the electricity grid can absorb all this energy at the time it is produced, then 100,000 wind-powered generators of this size would supply 300 to 350 million megawatt-hours per year, or about 15 per cent of present U.S. electricity use. There is certainly no problem in producing the machines; a wind generator is less complex than an aircraft. Wind surveys indicate that there are enough sites, though the certainty of this knowledge is not complete. The land requirement is not excessive, especially considering that a wind power installation will probably not conflict with other land uses. I am convinced that the prospects for wind energy are sufficient to justify a determined national effort, well funded and consistently pursued, to overcome the economic problems and demonstrate the engineering, which is not really in doubt. Scientific breakthroughs are not required. With the will to do it, large-scale use of wind energy can become a reality in the 1980s.

Suggested Readings

P. C. Putnam, "Power from the Wind," Van Nostrand (1948); reprinted, Van Nostrand Reinhold (1974).

E. W. Golding, "The Generation of Electricity by Wind Power," Philosophical Library (1955); out of print; obtain from University Microfilms, Ann Arbor, Michigan.

E. W. Golding, "Electrical Energy from the Wind," Proceedings of the Institution of Electrical Engineers 102A, pp. 667-695 (1955).

E. N. Fales, "Windmills," in *Standard Handbook for Mechanical Engineers,* T. Baumeister and L. S. Marks, editors, McGraw-Hill; the same article appears in many editions.

Proceedings of the United Nations Conference on New Sources of Energy, Rome, 1961. Published by the United Nations (1964; reprinted 1974). Vol. 7, "Wind Energy."

"Wind Energy Conversion Systems — Workshop Proceedings," J. M. Savino, editor. Conference held June, 1973, Washington, D.C. National Science Foundation Document NSF/RA/W-73-006.

"Proceedings of the Second Workshop on Wind Energy Conversion Systems," Frank Eldridge, editor. Workshop held June, 1975, Washington, D.C. Proceedings published by the Mitre Corporation, McLean, Va. Document NSF-RA-N-75-050; MTR-6970.

"Vertical-Axis Wind Turbine Technology Workshop" Proceedings. Lyle Weatherholt, editor. Workshop held May, 1976, Albuquerque, N.M. Document SAND 76-5586.

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The Local Economic Impact of Nuclear Power

Nuclear power plants differ from fossil-fueled plants: they cost more per unit of capacity, they take longer to build, they require refueling not more often than once a year, and — for reasons of safety — they are usually sited in rural areas, away from centers of population.

Many years' experience has given us a good basis for estimating the local economic impact of the construction of fossil-fueled electric generating plants. But the nuclear industry is so new that only fragmentary information is available on the consequences to local economies of nuclear power plants. The purpose of this article is to provide a preliminary overview, drawing upon published and unpublished data and upon interviews with local government officials, power companies, and trade union leaders.

Nuclear power plants, like large fossil-fueled plants, are usually sited in clusters, with at least two — and often up to six or eight — units being planned for each tract selected. Clustering provides economies in construction and operation of the plants as well as in transmitting electricity to regional power grids. A rural area selected for a cluster of nuclear plants experiences a construction project of extraordinary size and duration, exceeding that involved in building an airport and far exceeding that typical of an urban office building; and when construction is completed, the area acquires one of the most capital-intensive industrial facilities known.

The original cost of a nuclear plant with one generating unit is now reckoned in hundreds of millions of dollars, a sum which may approach or even exceed the value of all other structures in the town, country, or tax district. If several generating units are built, the utility's impact on assessed valuations and taxes may well be uniquely large.

To understand and predict the impact of nuclear plants not yet designed or built upon diverse and also changing rural areas is difficult. New nuclear units are larger than old ones, more expensive and time-consuming to build. The economic impact suddenly changes upon completion, and it will change once more upon decommissioning. Only inconclusive information exists on who will pay for decommissioning and for managing the radioactive areas which remain and how local property taxes will be affected.

Past Impacts: "Far from Overwhelming"

To date, the total economic impact of these huge industrial facilities upon the rural communities in which they have been built has been far from overwhelming. These low levels of overall economic change typical of nuclear plants mean that standard statistical measures such as are provided by the U.S. Bureau of the Census and the U.S. Department of Labor do not show variations which correlate with the presence or absence of a nuclear power plant. Detailed, local study is necessary.

Furthermore, it is necessary to interpret standard statistical measures differently for each locality and to rely on judgments by individuals in touch with local conditions. This implies the possibility of personal bias, both on the part of those supplying and interpreting information and on the part of those — including the author of this article — compiling the results. Fortunately, however, there seems to be a wide area of agreement on the subject of local economic impacts of nuclear plants. It is out of this area, as perceived by the author, that the material in this article has been drawn.

Construction: Skills Amid Unemployment

Most nuclear power plants now on line required three to five years for construction; those now nearing completion have been under construction five to seven years. Eight years will be required for completion of T.V.A.'s four-unit plant near Hartsville, Tenn., and ten years for the Philadelphia Electric Co.'s high-temperature gas-cooled reactor, a two-unit plant proposed for Fulton, Penn.

Peak employment ranges from about 1,200 for a one-unit plant to 5,400 for a four-unit plant. The number of construction workers on a site increases for the first half of the construction period and then decreases progressively. The mix of required construction skills changes from year to year but in general is characterized by a large proportion of skilled workers, particularly of steamfitters and electricians. The table on page 42 gives a breakdown of the work force by occupation for each year during construction of Commonwealth Edison Co.'s two-unit plant in Zion, Ill., completed in 1973 and 1974.

In three years between 1969 and 1972, municipal tax revenue in the little (population, 2,300) seashore town of Wiscasset, Maine, grew from $600,000 to $2.2 million — thanks to construction of the Maine Yankee Station (in the upper right hand portion of the picture) of the Central Maine Power Co. But the bonanza was short-lived; now Wiscasset makes the largest single payment of any town in Maine under a uniform state-wide property tax to provide per-pupil payments for education. (Photo: Roger Paul Jordan, Inc., from Central Maine Power Co.)

What happens on Main Street when a half-billion-dollar nuclear industry is built just outside town? So far in New England, not very much. But future plants will be bigger, and so will be their impacts

A total of 5,368 man-years of labor was required by over 1,000 workers to build the two-unit plant of Commonwealth Edison Co. in Zion, Illinois, between 1968 and 1974 — a total payroll of $134 million. (The figures do not include clerical workers, technicians, and supervisors, who together are estimated to add between 15 and 20 per cent to the figures shown.) The striking point of this data is that only 20 per cent of the total represented unskilled labor. Some 17 per cent of the skilled labor were nuclear-qualified welders, including one-third of the pipe/steamfitters, iron workers, and sheet metal workers and one-quarter of the millwrights and boiler-makers. New, larger reactors projected for construction in the future will require larger work forces.

	Year 1	2	3	4	5	6	7	Total
Estimated payroll (Millions of dollars at 1975 levels)	$4	$14	$24	$38	$28	$22	$4	**$134**
Skilled man-years:								
Pipe/steam fitters	8	33	155	423	427	293	13	**1352**
Electricians	2	7	53	353	299	174	8	**896**
Carpenters	49	174	203	148	62	40	2	**678**
Iron workers	25	88	148	111	52	57	3	**484**
Boilermakers	—	—	85	57	46	22	1	**211**
Operating engineers	16	46	45	57	37	22	2	**225**
Truck drivers	5	19	16	19	10	8	1	**78**
Insulation workers	—	—	—	—	—	117	13	**130**
Millwrights	—	—	—	23	34	31	6	**94**
Cement masons	3	12	19	39	13	13	76	**175**
Plumbers	—	—	26	26	14	7	1	**74**
Sheet metal workers	—	—	—	41	22	6	1	**70**
Unskilled man-years	33	183	228	239	120	92	6	**901**
Total	**141**	**562**	**978**	**1536**	**1136**	**882**	**133**	**5368**

The required pool of skilled workers is not likely to exist in the rural or small-town plant location, but the recruitment of construction workers has posed no special problems for plants which offered union rates of pay and were within commuting distance of a major city. Both these conditions existed at the six nuclear sites now in use in New England: only about 15 per cent of the workers moved their domiciles in order to come within commuting range of the projects. Those who did come from afar were able to find accommodation in existing houses, apartments, bedrooms, and mobile homes within a 30-mile radius of the plant sites. School enrollments did not skyrocket, public services were not strained, and retail stores could handle the extra business without enlarging their facilities.

Because the required pool of skilled workers did not exist in the purely local labor market, the local economic impact through employment was modest. For example, though Plymouth, Mass., must have had its economy stimulated by the construction of the Pilgrim Plant, Plymouth remained on the U.S. Department of Labor's list of areas having unusually high rates of unemployment throughout the decade beginning in 1965, during which the plant was built. Even in 1970, when construction was well underway, the decennial census showed that Plymouth (town) had a higher unemployment rate (6.2 per cent) than Plymouth County (4.3 per cent), which in turn had a higher rate than Massachusetts as a whole (3.8 per cent). This is evidence that the types of employment offered in building the Pilgrim Station did not match the skills of Plymouth's unemployed.

Another reason for the small local impact of nuclear construction in New England was that power companies and prime contractors took pains to consult with local officials, informing them about construction schedules and advising them about the desirability of zoning and other types of controls that might prevent shanty-town situations from arising.

On larger nuclear construction projects elsewhere, 20 to 30 per cent of the workers have changed their residence in order to claim jobs, and it has become more difficult to avoid stressful situations even with careful planning. The largest nuclear project yet proposed is that of the Tennessee Valley Authority at Hartsville, Tenn., where a four-unit plant is to be built. The T.V.A. has concluded that there will be no way to avoid an influx of workers into the counties near the project; about 500 are expected after the first year and 2,700 at the peak of employment. These 2,700 will be accompanied by about 1,700 school-age children and 1,700 other family members — a grand total of 6,100. Accordingly, plans have been made for constructing new conventional houses and mobile home parks, extending sewage systems, expanding health facilities, providing temporary classrooms adjacent to existing schools, and developing a mass transportation system utilizing buses, vans, and car pools.

Skagit County in Washington, where a two-unit 2,300-megawatt plant will be started in 1977, has worked out an interesting agreement with the Puget Sound Power Co. in order to avoid the common problem of a city being required to expand the educational and police protection systems to accommodate construction workers and their families before the plant being built generates significant taxes to pay for these services. In exchange for the county's rezoning the land into an industrial category, the company has agreed to, in effect, prepay future property taxes to the extent required to offset the cost of extra services.

An example of a construction project that did create a considerable — though not entirely unwelcome — impact is the $635-million, two-unit Brunswick Plant of the Carolina Power and Light Co. near Southport, Brunswick County, N.C. Construction started in 1969, with completion of the first unit achieved in 1975 and that of the

Position	Single-unit plant staff	Two-unit plant staff	Maximum monthly rates of pay, two-unit plant
Plant management			
Superintendent	1	1	Open
Assistant	1	1	$2,945
Operations			
Operations supervisors	1	2	2,678
Shift supervisors	6	6	2,198
Lead operations/foremen	—	5	1,800
Control operators	11	16	1,517
Auxiliary operators	11	16	960
Lead fuel handlers/foremen	—	3	1,390 and 1,670
Fuel handlers	—	6	1,390
Technical			
Technical supervisor	1	1	2,678
Professionals	6	9	1,610 to 2,198
Technicians	9	16	1,610
Maintenance			
Maintenance supervisors	1	2	1,800
Craft and repair men	18	28	938 to 1,428
Security	11	16	Contracted
Total	**77**	**128**	**$250,000** approx.

Though a nuclear power plant is a highly technical industrial machine, its operation requires relatively few people. This table shows the number of employees and monthly payroll as of June, 1975, at Commonwealth Edison Co.'s nuclear reactor at Zion, Illinois, completed in 1974. The Nuclear Regulatory Commission now requires more surveillance, testing, security, and clerical personnel than are shown in this table, and the author believes that employment levels — as of 1976 — may be as much as 50 per cent higher than shown here. Even according to that estimate, the number of employees and amount of their payroll is low considering the capital investment represented by a nuclear power plant.

other being scheduled for 1977. Employment peaked in 1972 at 3,400 workers instead of the anticipated 2,400 — an increase caused by delays in completing the designs. Brown and Root, the prime contractor, brought in many more outside workers than the Carolina Power and Light Co. had forecast in initial talks with county officials; some 1,700 workers moved into Brunswick County on a semi-permanent basis. Of these about half rented, purchased, or built conventional housing and half settled in mobile homes. The total population of Brunswick County increased 15 per cent, from 24,000 in 1969 to 27,600 in 1973, and school enrollment increased 25 per cent. Brunswick County was not prepared in terms of mobile homes and public services. Schools became overcrowded, retail stores experienced a large increase in trade, and the sewage system became overloaded.

Several factors contributed to cause this problem. Only about 200,000 persons resided within a 65-mile radius of the plant, and few were skilled construction workers. Furthermore, the nonunion pay rates of Brown and Root, while competitive locally in the low-wage area of Southport, were not competitive in certain other parts of nearby North and South Carolina; thus some construction workers within the commuting radius preferred to take jobs elsewhere. Training programs offered by Brown and Root were of marginal use because most of the workers who were trained in them switched to better-paid jobs with other employers in nearby areas. Indeed, Brown and Root had such difficulty finding an adequate labor supply that its recruiters were working as far afield as California.

Brunswick County was able to deal with this population influx in a constructive manner because the assessed value of the plant increased rapidly during the construction period, and the actual funds which became available through the property tax were augmented by funds borrowed in anticipation of even greater tax revenues later. So it was possible to build new schools and improve the quality of education to the point that in 1975, for the first time ever, all schools in the county were accredited.

No great exodus of population occurred immediately after peak employment was reached, because there were other large construction projects seeking labor nearby. More recently, however, an exodus has brought a drop in real estate values, in Brunswick County.

As they have in other towns close to nuclear plants, complaints arose in Southport from employers whose labor costs were increased as a result of the nuclear plant's competition for workers. Some employers were unable to survive this competition and went out of business; employers of agricultural labor producing commercial, perishable crops and local building contractors were especially vulnerable.

The Local Dealer Is Too Small

Procurement for any nuclear construction project stimulates industry over a wide geographic area and through many economic linkages, direct and indirect. There is no good technique for allocating the effect of procurement on the locality near the plant site.

Much of the machinery and equipment required is highly specialized and is bought as a part of unified systems supplied by the few companies qualified to manufacture them. For example, the reactor pressure vessel for the first unit of T.V.A.'s Browns Ferry Station, Limestone County, Ala., was manufactured in Ohio, and vessels for the second and third units were made in Japan. The reactor vessel for the Pilgrim Plant was manufactured in Chattanooga, Tenn., and shipped to Massachusetts by barge. The turbogenerators also usually come from afar.

Even most standard building materials are purchased in large quantities on the basis of competitive bids involving large-scale, often distant, suppliers. Unless a major or highly specialized supplier happens to be in the area, prime contractors' local purchases are likely to be

limited to day-to-day needs of sand, gravel, stone, lumber, and miscellaneous hardware.

There is general agreement among power company officials and local residents that local procurement for a nuclear plant has a small, though beneficial, effect on the local economy. They also agree that the construction workers who commute to work spend little money locally.

Living With a Capital-Intensive Giant

As the construction period is completed and a new nuclear plant goes "on line," employment falls to the relatively low level shown in the table on page 43. The educational prerequisites for most operating assignments are modest. Reactor operators typically have a high school education followed by specialized reactor training given by the power company. Senior reactor operators must have a year or two of college, conventional power plant experience, and more extensive specialized training. The plant manager and his assistant would normally have four-year college degrees. Because most qualifications and rates of pay are modest, the local payroll is likely to be about $2 million a year for a one-unit plant and $3 million for a two-unit one.

In addition to operating personnel, certain professionals, necessary to plant operations, but not on a

Would You Do It Again? A Resounding "Yes"

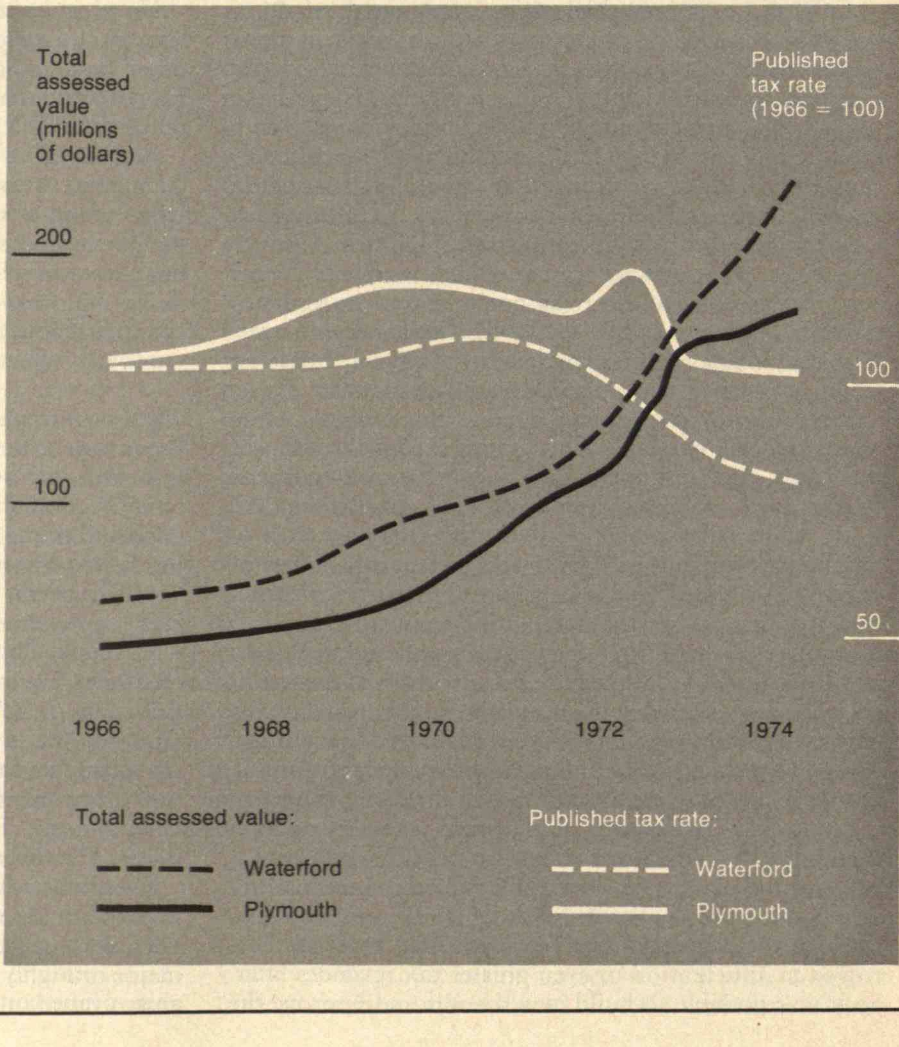
What were the economic and political/social impacts of the Pilgrim (Plymouth, Mass.) and Millstone (Waterford, Conn.) nuclear reactors on their host communities? "Minimal," say members of a social impact assessment team from Oak Ridge National Laboratory after a year-long study sponsored by the Nuclear Regulatory Commission.

There was "explosive" growth in the population of Plymouth (about 11 per cent a year) beginning in 1968 when construction of the Pilgrim Station began; school enrollments increased 108 per cent in the decade ending in 1975, and building permits doubled each year between 1970 and 1972. But regional growth patterns suggest that much of this growth would have happened anyway, Elizabeth Peele, Group Leader for the O.R.N.L. project, said at a conference on land use and nuclear facility siting sponsored by the Atomic Industrial Forum last summer. And "Plymouth's unemployment rate remains among the highest in the state (14 to 22 per cent since 1969) as it has for many years," said Ms. Peele.

Waterford, Conn., enacted "restrictive" zoning ordinances before construction of the Millstone Reactor began, and its growth (11 per cent during the entire construction period) was less than that of its region.

In both cases the major impact of reactor construction was on assessed valuation and, therefore, income from taxation (see chart). Both communities chose to stabilize existing tax rates while using the new revenues "to significantly increase public services and facilities." One exception: Plymouth elected to make a large capital expenditure out of current income in 1972 — hence the one-year tax-rate increase shown.

Surveying residents' views, the O.R.N.L. group asked, "Would you permit construction of the nuclear plant again?" Of 126 Plymouth residents, 72 per cent said "yes"; and 94 per cent of 182 Waterford residents gave the same answer. — *J.M.*



The economic impact of a nuclear power plant on the community in which it is located is chiefly in the form of taxes: property tax income goes up and tax rates are stabilized. Residents' enthusiasm for nuclear plants built in Plymouth, Mass., and Waterford, Conn., is attributed by an O.R.N.L. survey team chiefly to this effect on residents' pocketbooks.

day-to-day basis, are usually on the payroll of the company headquarters. These would include nuclear physicists and engineers who may be assigned temporarily to whichever plant or project requires their expertise, as well as technical and blue-collar personnel who perform the corrective non-routine maintenance occasionally required.

The annual refueling operation is not likely to be a source of significant local employment. Boston Edison Co., for example, contracts for refueling its Pilgrim Plant with General Electric Co., which brings in a group of some 40 shipfitters, riggers, and other specialized personnel and arranges for help from a subcontractor who employs about 80 shipfitters, riggers, pipefitters, and laborers; these are obtained from union hiring halls nearby.

The logistics of keeping a nuclear plant operating involves frequent replacement of sophisticated instrumentation and equipment and replenishment of industrial gases. Local merchants usually cannot supply these goods in bulk at competitive prices. The lifeline between the plant and the industrial suppliers consists of trucks which haul the costly — but not bulky — products to the plant.

The power generated goes out through extra-high-voltage transmission lines into the regional power grid. Regulatory bodies usually require that the price of power sold to distributing companies be based upon the average costs of all generating units contributing to the grid. Thus proximity to a generating unit is not a source of competitive advantage for power users near the generating plant.

Few Losses Match Few Gains

If plant operations do not appreciably stimulate the local economy, neither do they hurt it. Most residents of towns in which nuclear plants operate seem to be confident that the plants are safe, and they seem unconcerned about the Price-Anderson Act and its limitations on the power company's liability for the consequences of major accidents. Land use in the immediate vicinity of a nuclear plant usually is the same as it was before plant construction.

Cooling systems of power plants affect aquatic life in many ways. The most dramatic have been the occasional kills of schools of young fish — chiefly anchovies on the West Coast and menhaden on the East. More important have been the routine, day-to-day impacts. The heated discharge water may cause organisms to spawn prematurely, at times when food for the young may not be available. Organisms acclimated to life in the heated effluent may experience thermal shock when the plant is shut down for refueling or repairs. Organisms small enough to pass through intake screens are subjected to a variety of stresses including heat, mechanical injury, and biocidal additives. Combined stresses result in the mortality of virtually all entrained plankton. Fish and other organisms that swim into effluents to prey on injured organisms are themselves subjected to heat and additives. Although sportsmen fish with unusually great success in effluent flumes, commercial fish catches elsewhere may be decreased.

A Dim View of Secondary Benefits

The use of a site for a power plant limits but does not preclude other uses. The hydroelectric systems created by the Tennessee Valley Authority not only produce electricity but also control floods, create navigable waterways, improve public water supplies, and provide attractive lakes for boating, fishing, and other recreational activities. In addition, reservoir shorelands set aside for public use enhance the local tourist and recreation industries. Similarly, nuclear power companies, as a part of their local public relations programs, normally encourage public use of a considerable part of the plant site, reserving only a few hundred acres for the plant proper. For example, the site of the Calvert Cliffs Plant in Maryland comprises 1,135 acres, stretching along a 9,000-foot shoreline; the plant and associated equipment occupy only about 100 acres of land and 2,000 feet of shoreline, and the public is allowed access to most of the rest. In these ways, nuclear plants contribute — if slightly — to the economy.

Three principal problems arise in connection with public use. One is that access may have to be denied when construction projects are undertaken and entrance roads are preempted by heavy trucks. Another is that power companies cannot be assured that the costs involved will be considered a legitimate business expense by the regulatory bodies that set rate structures. (In hydroelectric plants, such costs can be passed on to consumers because the Federal Power Act requires multiple use.) The third problem arises out of concern about the security of nuclear power plants; to prevent terrorist attacks and sabotage, stringent security regulations not entirely compatible with public access are now being imposed.

The potential uses of the waste heat from the cooling water may include applications to fish farming, open-field agriculture in which irrigation is required, and hothouse production of vegetables. Unfortunately the economic obstacles to these uses are overwhelming. The temperature of nuclear-plant cooling water in a once-through system ranges from about 60° F. in the winter to 90° F. in the summer (slightly higher in a closed-cycle system), and there is no ready-made market for such lukewarm water. Nor are the prospects good for creating a significantly large one. An open-field farm one square mile in area would dispose of less than one per cent of the waste heat of a 1,000-megawatt reactor. Long interruptions of supply might occur when reactors close down for refueling or repair. Farmers would need the heated water only at certain times of year, and pipes and pumps would represent a prohibitively high initial investment.

Tax Benefits: From Nil to Extravagant

Nuclear power plants usually require little in the way of costly public services from the tax districts in which they are located. But since they constitute a sizeable proportion of the tax base, they may contribute greatly to local revenues. Whether or not they do so depends upon laws which differ greatly from state to state. The net difference between income and expenditure ranges from nil to enormous, as can be seen from the examples reviewed below. But tax laws are changing; there is pressure everywhere — perhaps stimulated by the extreme situations created by the siting of nuclear power plants in small communities — to equalize the capacity of local governments to fund public services in general and schools in particular. These on-going changes make it difficult to predict future tax benefits. The potential revenue from property taxes has already been greatly reduced in most states by statutory exemptions of one or more of the following: nuclear fuel, industrial machinery, and equipment and structures related to safety or to lessening environmental impacts.

The towns harboring the nuclear power plants at Peach

Bottom, Shippingport, and Goldsboro, Pennsylvania, receive almost no tax benefits. Before 1970 Pennsylvania power plants were not subject to property taxes. In 1970 plants became subject to a state property tax, an arrangement specifically designed to prevent windfall profits in areas which had a high concentration of public realty. The state distributes the revenue to all tax districts on the basis of the amount of tax revenue each township raises on its own behalf.

In states served by the Tennessee Valley Authority, tax benefits may be minimal. The T.V.A., being an agency of the federal government, cannot be taxed by other units of government. But T.V.A. does make payments in lieu of taxes, and the construction of a new power plant tends to increase the amount of these. But these payments are made to states, not to the local units of government. Some states redistribute part of the T.V.A. payments to localities, but no such redistribution takes place — for example — in Alabama. Thus Limestone County, the site of the T.V.A.'s three-unit Browns Ferry Plant, receives no property tax revenue from the plant and no payments in lieu of taxes. Tennessee reimburses counties for "theoretical" taxes on land (only); the assessed value of the land in Smith and Trousdale Counties on which T.V.A.'s four-unit Hartsville Plant is to be built will be increased, and these counties will thus receive a small tax benefit.

But in most states tax benefits are large. Wiscasset, Maine, a town of 2,300 population, has enjoyed such an impact. Construction of the Maine Yankee Station, a single-unit plant started in 1969 and finished in 1972, raised the town's total municipal tax revenue from $0.6 million to $2.2 million; in 1974 Maine Yankee was responsible for about 85 per cent of the total property tax income of the town. This considerable tax benefit was not used to lower the tax rate but to improve the town. The fruits include a new primary school, an addition to the high school, a municipal garage, many sidewalks, an updated sewer system, some rebuilt streets, a new fire engine, an expanded Police Department, a new health center, and numerous projects designed to beautify the town. In addition, the revenue from the Maine Yankee Station has been used to keep Wiscasset's tax rate low when that of nearby townships was rising.

But the bonanza was soon tapped by the state government. On July 1, 1975, the state of Maine sought to equalize investments in public education in all towns in the state by providing funds at a uniform rate per pupil to all towns. This funding is obtained by assessing and taxing the value of all property in each town at a uniform rate. Wiscasset, because of its nuclear power plant, has the largest tax bill — $289,000 per month to be paid to the state — with the expectation of receiving back only $250,000 once a year.

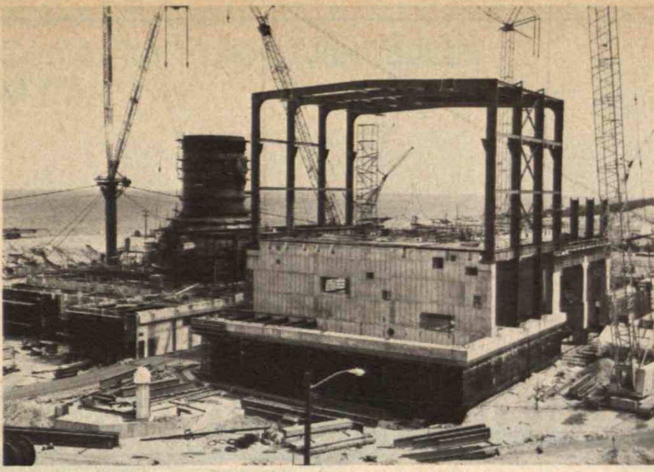
Wisconsin's tax law created an amusingly high tax benefit for the town of Two Creeks (population 600) as the Wisconsin Electric Power Co. built first a fossil-fuel plant and then a two-unit nuclear power plant there. Before 1971 towns in Wisconsin could not tax the property of power companies but were entitled to a share of the proceeds of utility taxes levied on such property by the state. The revenue received by Two Creeks under this law rose from about $10,000 in 1967 to about $1.6 million in 1971. Then the tax law was amended, with the result that the amount of shared revenue was $460,000, about four times the amount of the total town budget before the plants were built. Now Wisconsin's Department of Revenue seeks a new amendment to equate the amount a town can receive from shared revenue on the utility tax with that which the town spends on services for the utility.

Utility officials fear that legislation of this kind adopted by many states may reduce the incentive which potential tax benefits provide to public acceptance of new power plant construction. This would add to the already difficult and time-consuming process of acquiring sites and obtaining the necessary permits to build and operate plants.

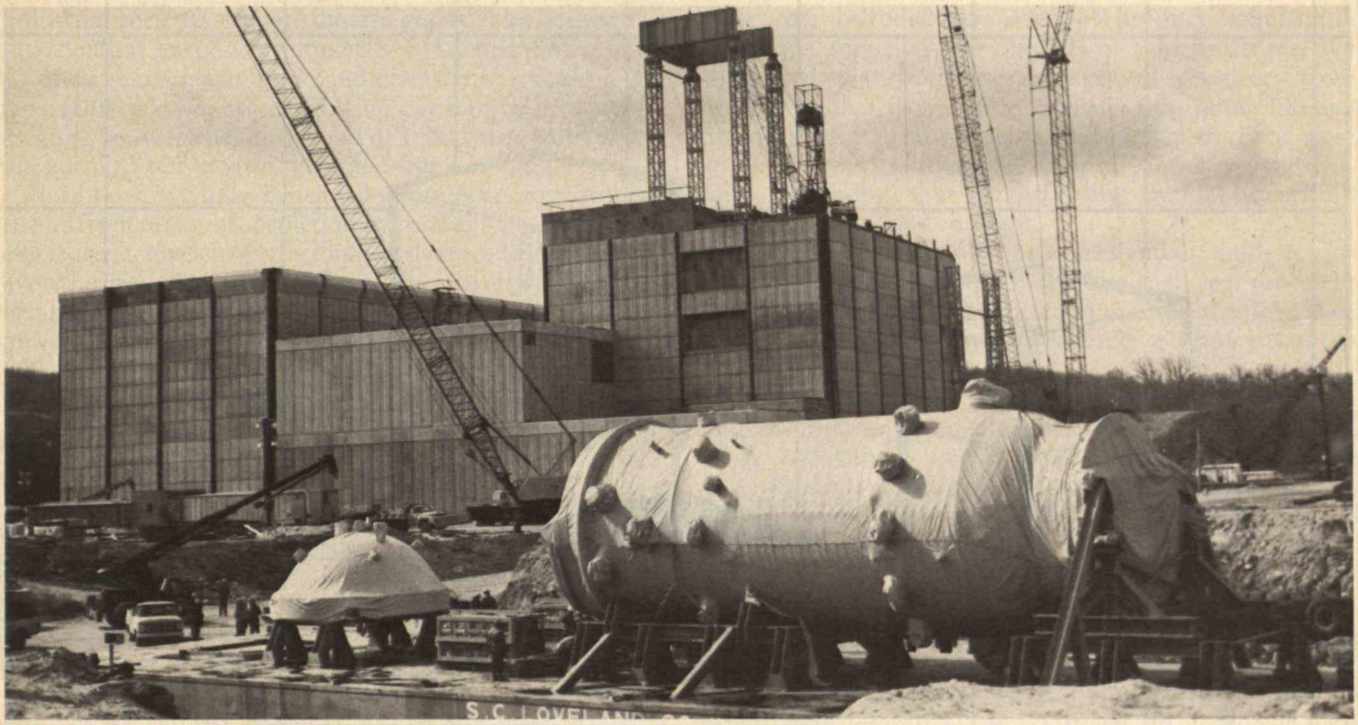
Other tax factors associated with nuclear plants are at best hard to estimate, because they are indirect and because they vary from state to state. These include the secondary effect of the plant through local sales and payroll taxes.

Forecasts of future economic impacts must be qualified as speculative for many questions remain unanswered. We do not know what will happen to tax benefits when nuclear plants are decommissioned. Will the cost of denying public access to entombed radioactive structures (for the 100 or more years considered necessary by the Nuclear Regulatory Commission) become a burden upon local taxpayers? Will one generation of nuclear plants be replaced in the local tax base by succeeding generations on the same site, as has usually been the case with large fossil-fuel plants? If real or perceived improvements in nuclear plant safety permit locating future reactors nearer to cities, economic factors will change. Future amendments to property tax laws are another important but speculative matter.

Though a completed nuclear plant has few strong linkages with the local economy, host communities tend to



What happened to Plymouth, Mass., in the five years required for construction of Boston Edison's Pilgrim Station (left and below)? Not very much. Throughout the period of construction, unemployment remained a problem in Plymouth, and the local economy was only modestly stimulated by the multi-million-dollar project. This was because the required skilled labor, not available in Plymouth, was drawn from the nearby metropolitan areas from which workers could commute, and because specialized materials were supplied directly to the site by large contractors not represented in Plymouth. (Photos: Boston Edison Co.)



demonstrate long-term economic growth tied mainly to growing populations and hence to increasing demand for consumer goods and services. Several factors seem to be at work here, and it is hard to know how each should be evaluated.

In some tax districts having nuclear plants, populaton growth has been accelerated by real estate developers who recognize that the combination of low property taxes and good public services will be attractive to prospective buyers; thus the plant indirectly becomes a source of growth in population, town services, and commerce.

Three criteria for nuclear plant site selection operate to bias the choice toward smaller towns and even villages, many of which have considerable potential as "bedroom" towns for commuters, as retirement communities for the elderly, and as vacation resorts. These criteria are that the site be not too near nor yet too far from a population center (that is, from a load center of the regional power grid), that the site adjoin some large body of cooling water, that there be ample vacant land, and that it will be accessible from some major highway. Thus much growth might have taken place without any impetus from the nuclear plant.

Suggested Readings

The Social and Economic Impact of a Nuclear Plant upon Montague, Massachusetts, and Surrounding Areas. Boston: Harbridge House, Inc.

Isard, W., Reiner, T. A., and Van Zele, R. L.: *Regional Socio-Economic Impacts of Nuclear Power Plants.* Philadelphia: University of Pennsylvania, 1976.

Yarosh, M. M., Nichols, B. L., Hirst, E. A., Michael, J. W., and Yee, W. A., *Agricultural and Aquacultural Uses of Waste Heat.* Oak Ridge, Tenn.: Oak Ridge National Laboratory, 1972.

Publications of the Atomic Energy Commission:

Projections of Labor Requirements for Electrical Power Plant Construction, 1974-2000 (1974).

Thermal Effects of U.S. Nuclear Power Stations (1971).

Utility Staffing and Training for Nuclear Power (1973).

Publications of the Tennessee Valley Authority:

Browns Ferry Nuclear Plant: Construction Employment Impact (1974).

Final Environmental Statement, Hartsville Nuclear Plant (1975).

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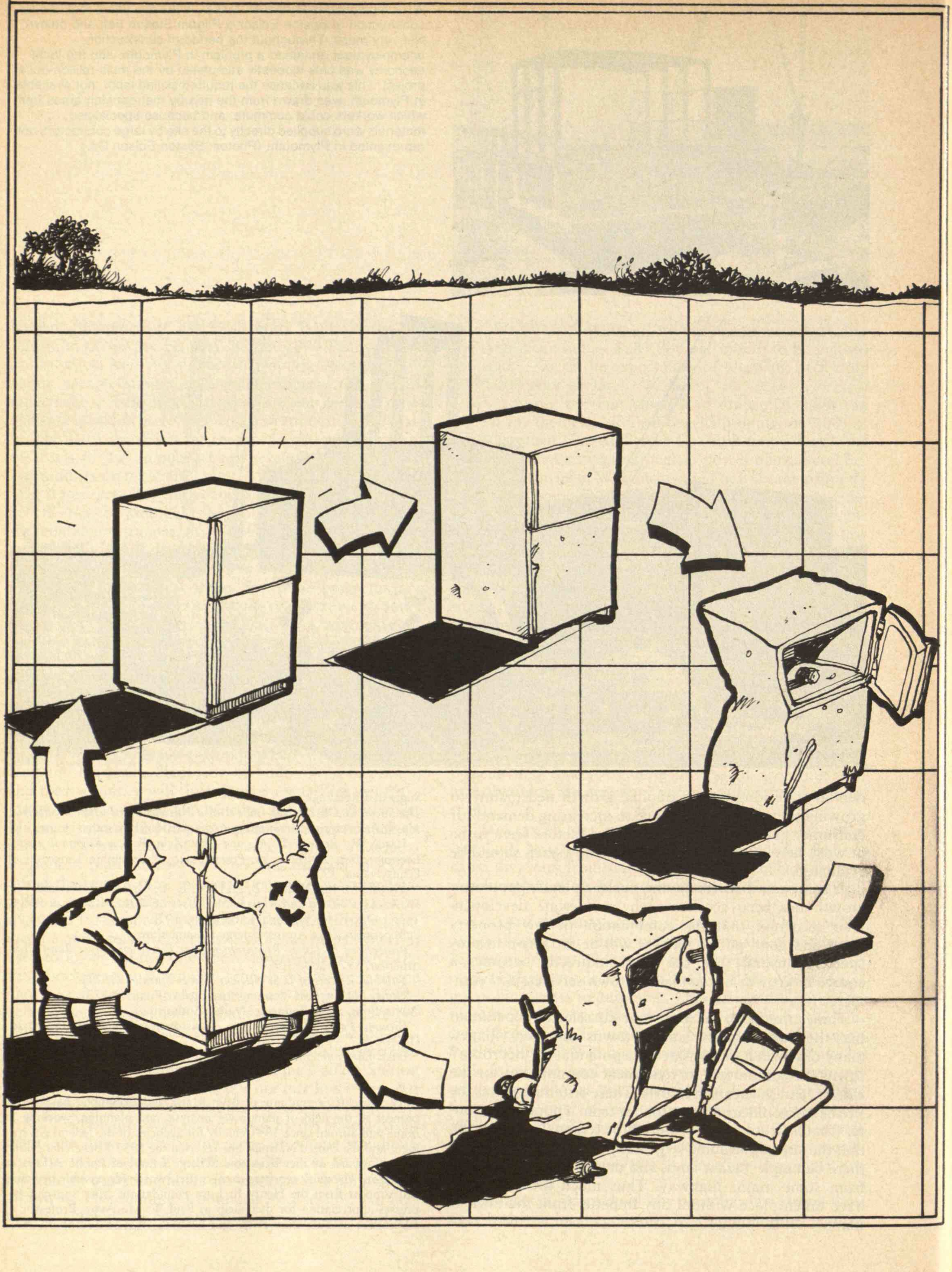

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Everybody talks about recycling to save resources. But another strategy might be to make products longer-lived in the first place. The case of household appliances shows the social and technical problems

Making Products Live Longer

Industrial societies use and discard goods at an enormous rate. Seldom are goods completely consumed during use. As our rate of consumption and discard has mounted, so have fears that we are exhausting our natural resources, creating an overwhelming flood of solid wastes and causing harm to our environment and our economy.

Until now, we have depended upon technology to rescue us from materials depletion by providing larger, more efficient machines to extract materials from leaner ores in ever more remote locations. The capital-intensive technologies that have evolved, however, themselves use prodigious amounts of energy, and rising energy costs will undoubtedly cause an escalation of materials prices.

Recycling has proven modestly successful in reclaiming energy and materials, but recycling does nothing to reduce the steadily increasing volume of solid waste. Further, the total social cost of waste collection and recycling is far greater than the total value of the materials and energy that are reclaimed.

Product discard involves another form of economic loss. There will always be a very great gap between the market value of a manufactured product and the materials in it that are recoverable as scrap. Whether the item is a non-reusable beer bottle or the refrigerator that cools it, the scrap value of its materials is only a small percentage of the value of the item "in its prime." The difference is in the *value added* — the labor and overhead costs of making and distributing the product.

This immense value-added gap holds the promise for economic gains from strategies that would either prolong the useful life of a product or find some intermediate levels of use that preserve much of the original value and delay the time when the product sinks to its scrap value.

A policy of increasing product life through either of these approaches would complement recycling — increasing consumer real income, reducing demand for resources, and lessening solid waste and its environmental impacts.

In 1973, the Center for Policy Alternatives at M.I.T. began a major study on life-cycle costs of appliances such as refrigerators, dishwashers, freezers, washing machines, dryers, television sets, and ranges. The concept of life-cycle cost included the costs of product acquisition, operating, servicing and disposal of the appliances. We concluded that both the recovery of resources from appliance discards and the extension of product life had potential value, and recommended further study of these areas. This article describes some preliminary investigations following that study, using major household appliances as a case in point.

The 2.2 million tons of appliances and 0.5 million tons of television sets discarded in the U.S. each year represent only about 1 per cent of the total municipal solid waste produced. However, we considered it appropriate to study this product category for the study because appliances have many characteristics in common with a larger variety of products — automobiles, housewares, tools, agricultural implements, commercial equipment and industrial machinery. Like these products, appliances have high initial value, a significant portion of which is value added (labor, energy, cost of capital). They are assemblies of parts, most of which can be replaced if they break or wear out. They often can be disassembled to the subassembly stage without damaging the subassembly, and even at time of discard will contain parts and subassemblies still in good working condition. All are *durable goods,* that is, they are expected to perform their functions over an extended period of time. They have a product life, in contrast to the single-use, throw-away items in our economy, such as packaging materials, newspapers or food. Thus, what we learn about the lives of appliances may apply to a wider array of products.

A first step in determining whether it would be worthwhile to build longer-lasting appliances, is to learn about the costs associated with appliances over their lifetimes. It turns out this is no easy matter.

Life-cycle Costs

In the business world it is common practice to evaluate capital machinery investments in terms of total expected costs over the probable life of the equipment. However, this approach has only recently become preferred in government procurement, and is not used at all by the average consumer. In the consumer's case, the problem has been lack of pre-purchase information. The consumer has not been able to appraise the complete life-cycle costs of his contemplated investment because, out of the array of costs implicit in his purchase decision, only the purchase price is available to him. Furthermore, the number of years that a product can be expected to last could be known only through experience.

Discarding an appliance or other such product wastes a considerable amount of value-added in constructing it. Manufacturing a product so that it could be refurbished, or so that its components would be longer-lived could preserve some of this value. (Drawing by Jon McIntosh)

The scrap value of a manufactured item is only a small percentage of the item in its prime. Longer-lasting appliances and other products would preserve some labor and production value (from Sullivan, et al., 1973; material weights given in Harwood, 1974).

	Retail value, new (dollars)	Market value of recovered materials (dollars)	Per cent of retail value
Cooking range	300	2.88*	0.96
Refrigerator	450	8.75*	1.94
Dishwasher	275	3.50*	1.27
Clothes washer	275	5.92*	2.15
Clothes dryer	175	2.72*	1.55
Beer bottles (empty)	.032	.0024*	7.5
Automobile	4,000	60†	1.5

* Sullivan, et al 1973
† Based on materials weights given in Harwood, 1974

The 1973-74 study at M.I.T. presented, for the first time, a comprehensive "buyer's-eye view" of the life-cycle costs of two major household items — refrigerators and color television sets. The study revealed that, for both appliances, future costs did represent a significant fraction of the consumer's total commitment, even when those costs were discounted to present value. Energy costs for refrigerators, for instance, constituted 58 per cent of the total life-cycle costs, even at 1972 pre-energy crisis rates. For television sets, the largest future cost was service and repair, at 35 per cent of total life-cycle cost.

Over the years there had been an encouraging downward trend in all the costs for television sets. Product design changes such as solid state circuitry had produced lower initial purchase prices, lower power consumption and higher reliability. For refrigerators, however, power costs were rising, counter to the other cost trends. This led to an appraisal of current refrigerator design and the finding that energy consumption could be reduced by as much as 50 per cent without eliminating most of the desirable features of present-day units (*see* Technology Review, *January, 1976, p. 76)*.

Life-cycle costs have proved to be effective as a research tool in locating diseconomies in the consumer goods sector. It remains to be seen, however, whether this technique or some derivative of it can be shifted from being a research tool into everyday use by the average consumer.

The Product Life Puzzle

An appliance's lifespan is, of course, a critical measurement, for life-cycle costing and determining the rate of appliance discard. Data sources are scarce. We are aware of only four studies on the subject in the past 20 years — a 1957 study by Battelle Memorial Institute, a 1967 study by the Department of Agriculture, a 1970 study by an appliance manufacturer, and a 1972 study by the Department of Agriculture. Results of the latter three studies, which used similar methodologies, are shown on the opposite page.

These studies indicate that there has been little change in service lives of new products, at least over the 15-year period bracketed by the three studies. Between the two most nearly comparable studies, the 1967 and 1972 Department of Agriculture surveys, the trend, if any, seems to be in the direction of shorter product life. Appliance manufacturers have generally not conducted product life studies. If they have, they have not published the results. They are concerned, and probably rightly so, that the consumer would misconstrue a life expectancy figure to mean that he is assured of at least that many years of life from his appliance.

From a technical point of view, there is no question that longer-lasting appliances could be made; this is freely agreed upon by the manufacturers. There are two technical approaches to this end. First, each component of an appliance could be designed for maximum durability: materials would be selected for wear and corrosion-resistance; gear trains would replace rubber belts and pulleys; sensitive parts would be sealed from the atmosphere; and circuits would be made more tolerant of ambient variations in humidity, altitude, line voltage and human error.

Or, appliances could be built in which everything is easily and economically repaired. Even cosmetic items such as exterior panels, doors and trim would be renewable or replaceable, so appearance could be maintained as readily as operating effectiveness. Costs of replacement parts or service labor could be reduced considerably by greater use of modular components and more standardization of parts between models or even between parts.

One variation of this second approach is to make the

Three studies of appliance lifetimes show virtually no change in the service lives of new appliances, at least in the time period between the studies. In the two Department of Agriculture studies, the expected service life figures represent life expectancies from age zero, similar to those obtained from life-expectancy tables. Data were collected only for appliances under one owner. (The 1957-1961 study was conducted by Pennock and Jaeger, and the 1972 study by Ruffin and Tippett — see Suggested Readings.)

	1957-61* (Dept. of Agric.)	1970* (Mfrs. Study)	1972* (Dept. of Agric.)
Room airconditioners	—	12	—
Ranges: electric	16	16	12
gas		16	13
Freezers	15	18	20
Refrigerators	16	15	15
Dishwashers	—	10	11
Clothes washers	10-11	10	11
Clothes dryers:			
electric	14	12	14
gas		12	13
TV sets: black and white	11	—	11
color	—	—	12

* Date of data

appliance readily remanufacturable. A worn-out appliance could leave its original owner to be reprocessed and sold again as a "like-new" appliance to another customer. Such reprocessing would maintain most of the original value of the appliance and save it from discard.

Of course, the alternatives of designing for durability and for repairability might both be used for different parts of the same appliance. Where replacement is impractical, as with the basic chassis of an appliance, parts could be designed for maximum life. Where replacement is feasible, as with motors or transmissions, a trade-off situation would arise between maximum durability of parts and shorter-lived, but easily replaceable parts. Manufacturers would adopt different strategies depending on the nature of their product, the market sector they wish to reach, and the extent to which they control service facilities.

Although, technically, appliances *could* be made to be more durable through improved product design, indications are that product durability does *not* govern the life of consumer durables. In fact, there is evidence that today's appliances may be more durable than their predecessors, even though they are not longer-lived. The M.I.T. study showed that the reliability of both refrigerators and color television receivers had improved significantly in the recent past. First-year service incidence (frequency of need for repair service) for refrigerators declined 50 per cent in a 14-year period from 1958 to 1972. The service incidence rate for television sets declined over 50 per cent in only eight years, between 1965 and 1972.

Logically, increases in reliability of a product usually imply increases in its durability, and increased durability should mean increased product life. But in the appliance industry this has not been so. Products are being discarded that still function or that could be repaired, indicating clearly that factors other than durability are affecting consumer decisions to discard appliances. The same has been suggested for automobiles. While we do not yet understand these factors and the degree of their influence, they must be considered if policies are to be developed to encourage longer product life. Among the factors that may influence consumer behavior are:

— *Rising service costs relative to new appliance prices.* The appliance manufacturing industry is justifiably proud of its record of price stability in the face of rising costs. Between 1955 and 1973 consumer prices for appliances, radios and television sets declined 17 per cent, counter to the trend in the overall consumer price index, which rose 66 per cent in the same period. The cost of household repair services, on the other hand, rose 106 per cent in the 17 years from 1956 to 1973.

The decreasing differential between purchase costs and maintenance costs may help explain the absence of any improvement in appliance service life. Owners who face the prospect of repairing an appliance find it more attractive to buy a replacement than to spend an appreciable fraction of that purchase price in repairing the old unit.

— *The effects of consumer affluence.* With people's income rising and appliance prices remaining constant or falling, there has undoubtedly been some upgrading of appliances in many American homes. Larger refrigerators, color TV replacing black-and-white, self-cleaning ovens replacing manual-clean ranges and other such changes have stimulated the appliance market and kept product lives shorter than might have been possible.

— *Weak used appliance market.* In contrast to the used car market, there is only a modest organized used appliance market. The used car market has both wholesalers and retailers. Autos are transferred from dealer to dealer, from market-surplus areas to market-demand areas, but appliances remain in the community where purchased or traded in, and there is virtually no organization of the market. The proportion of sales in-

volving a trade-in varies with the appliance. The fraction of these which are junked also varies. Only 3 per cent of dishwashers survive a trade-in, whereas over half of television sets traded in are restored to use. Appliance marketing data indicates a generally declining trend in resale of trade-ins.

— *Population mobility,* a fact of life in America, causes appliance turnover, with many appliances falling victim to home remodeling and/or differences in owner preferences.

— *Appearance* may be a factor where the scratched, worn, or out-of-style exterior is a cause of "death" even when the unit is functioning perfectly well.

— *Unavailability of replacement parts* for an older appliance is undoubtedly a cause for discard in many instances. Suppliers find it uneconomic to carry stocks of parts for many years, especially when the parts are peculiar to a specific model.

All of these reasons may combine with technical problems in appliances to cause premature discard. In effect, these are the obstacles to be overcome if increased product life is to be possible.

Longer Appliance Life: Good News . . .

If, by 1980, we could increase the service-life expectancy of all appliances by one-third, the benefits would be considerable, but there would also be penalties.

The largest single economic benefit would be the potential reduction in annual consumer expenditures for new appliance purchases. A one-third longer life means a 25 per cent reduction in the number of appliances purchased each year. The potential saving in 1980, assuming that expenditures for appliances would otherwise follow historical growth patterns, is 4.5 billion dollars.

A second social benefit would be the potential reduction by 25 per cent in the annual volume of appliance discards. By 1980 the total appliance discard rate may reach nearly 6 million tons annually. A saving of 1.5 million tons of solid waste would save upwards of $35 million a year in municipal waste collection costs alone. Of course there would be non-tangible environmental benefits in waste reduction, such as fewer unsightly dumps, as well.

A lower demand on resources is the third major benefit of a one-third longer appliance life-span. To the extent that consumer savings from increased product life are not channeled into other goods purchased, a reduction in resource use would result. On the basis of current usage rates per unit and expected 1980 sales volumes, a one-third longer appliance life-span could reduce steel use by about 1.1 million tons; copper by 70,000 tons; and aluminum by 35,000 tons.

These are potential savings, however, and they may not be completely realizable. Longer product life may require the use of more materials per unit, thus nullifying to some extent the reduction in resource demand. This would also tend to increase prices of appliances, cutting the anticipated expenditure savings to the consumer. As we have said, however, non-technical reasons may govern the length of product life. Whether the savings are obtained thus depends on the approaches taken to increase product life, and these, in turn, depend on the incentives society offers to accomplish the objective.

. . . . And Bad News

There may be adverse effects from an extension of product life as well. A 25 per cent reduction in appliance replacement buying might cause an actual drop in production output, resulting in unemployment and lower profits. However, the projected rate of new household formations promises to sustain a growth in demand for appliances for more than a decade. This new demand might offset the decline in the replacement market, and thereby ease the effects of lower replacement buying. In the long-term, annual sales of appliances will be lower than if product life remained constant. Whether this is a good or bad effect is a matter of debate for economic philosophers.

Increasing product life, some claim, will slow down the adoption of technological innovations. For very new products, this would perhaps be a serious consideration. However, for mature products such as refrigerators or washing machines the rate of innovation has already slowed. Beneath the exterior trim of many of these products are gear trains, compressor systems, and other mechanisms that have remained essentially unchanged in design for 20 to 25 years. In a world where markets for goods are expanding internationally, the reduction in the replacement market in a few countries should not be sufficient to stifle industrial creativity. Also, the level of annual demand for any of the major appliances would be in the millions even with a 33 per cent increase in product life. Competition between firms for shares of that market would continue to stimulate and reward innovation.

Changing consumer buying practice could be the key to accomplishing longer product life and with reasonable speed. If the problem were solely one of product durability, it might take 15 or 20 years before existing populations of appliances were replaced by more durable

Building longer-lived appliances might reduce the flow of solid waste and shrink the nation's junkheaps, but it might also slow the production lines

models. If the problem were only consumer attitude, however, the change could be rapid. During World War II, for instance, the service-lives of all consumer equipment had to be extended indefinitely. There were no replacement appliances, and the average age of consumer durables climbed. In 1941 before the U.S. entered World War II, the average age of an automobile in the U.S. was 5.5 years. By the end of the war in 1946 it was 9.0 years. It took until 1957 for the average age of automobiles to return to the pre-war level. A mild reversal in the declining average age of passenger cars appears to be occurring at present because the energy crisis, inflation and recession seem to have induced consumers to hold onto their cars longer.

What We Must Know

Our current understanding of the forces governing product life is so rudimentary that it is premature to develop comprehensive policy recommendations. We need to study several areas to gain a clearer idea of the possible outcomes of the various alternatives. These include:

— *Reasons for product discard and the relative number of discards for each appliance.* Information about why consumers discard products can give insight into the question of appliance durability versus consumer attitude, and will help determine where to put emphasis in setting policy. Such motivational studies should probably be combined with a demographic analysis of what type of household unit discards appliances at what age.

— *Service incidence rates for appliances over their entire lives.* No information exists on the actual rates of appliance failure over the full life of any of the consumer durable products as they are used in normal households. The only relevant data are from early product life during the warranty period. As shown on page 54 a typical curve of reliability experience indicates a high initial incidence of failure — due largely to materials and manufacturing defects — followed by a lower constant level of failure due to stress or time-related causes, and, finally, a rising level of failures due to wear-out or fatigue. If we knew the actual shape of service incidence curves for appliances we could identify the stage in the life of an appliance where it is economically infeasible to continue to repair the unit by calling in a serviceman. This point would be the end of the economic life of the product.

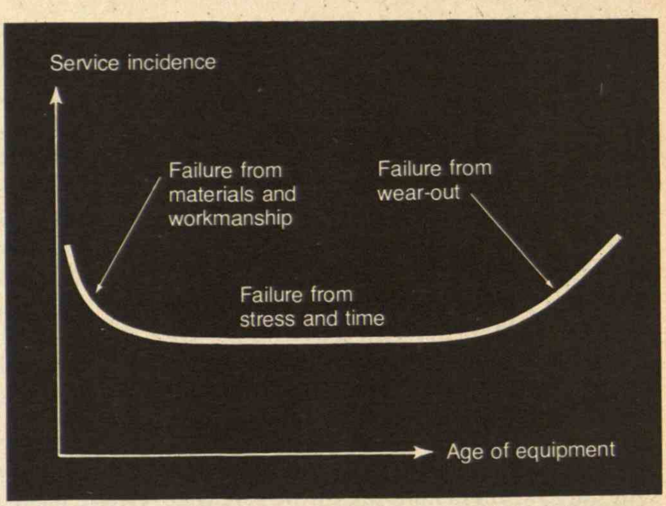
— *The nature of second-hand equipment markets and of used parts markets.* A comparison between the used appliance market and the used car market would indicate whether a more vigorous used appliance and used parts

Photo: Stock, Boston

market would be possible, and whether changes in policy would be effective in promoting such a market.

— *Appliance remanufacturing.* Rebuilt engines, carburetors, fuel pumps, and generators are commonly available for U.S. automobiles. It is conceivable that gearcase assemblies, water pumps, motors, timers, and other subassemblies of appliances could be rebuilt and sold as replacement units. This might reduce the cost of repairing an appliance failure, because a trade-in allowance could be given for the defective unit returning for rebuilding. One major television manufacturer already maintains a production line for remanufacturing circuit modules that have been returned from the field. Alternatively, entire appliances might be remanufactured and resold. The logistics of systems for rebuilding appliances and components should be explored.

— *Economic consequences of longer product life.* The potential savings described in this paper are very tentative figures, and the social and economic costs have not been estimated. If product changes are necessary for longer product life, for instance, prices of appliances might be higher, and savings to the consumer would be reduced. Effects on employment and industrial income must also be studied.



The typical curve of failure rates of new appliances shows a high initial failure rate — due to materials and manufacturing defects — followed by a lower rate due to stress, then an increasing rate due to wear-out.

A First Shot at Policies

While our knowledge is limited, we can at least speculate on the types of public policy that might be effective in promoting longer consumer product life.

One strategy would be to reduce the cost of appliance repair, so the consumer is more inclined to repair an appliance than to discard it. Encouraging companies to produce more easily serviced products, or inviting more competition in the aftermarket for replacement parts might accomplish this. One approach at the consumer level might be to allow taxpayers to deduct the cost of appliance repairs from their taxable income.

A second possible direction for policy application is to reduce servicing costs relative to purchase costs. In addition to the approaches described in the preceding section, it would be possible to increase new appliance prices without causing higher servicing costs. Prepayment of the social costs of collection and disposal of an appliance — in the form of a tax on the new appliance — is one such approach. A disposal cost assessment to the customer at the time of discard would serve a similar purpose.

A third area for policy development is in encouraging remanufacturing. This could mean technical assistance, government-guaranteed financing or public subsidies of the new enterprises. One form of subsidy might be to use municipal waste collection facilities as a means of assembling discarded appliances for remanufacturing.

Reducing the uncertainty of future repair expense through some form of extended service contract would encourage consumers to continue repairing appliances when they fail. The service contract would perform an insurance-like function to reduce the impact of major repair expense. The occurrence of failure in an appliance is an uncertain event. When several failures occur in the same appliance within a fairly short time, the consumer is likely to believe that the appliance is wearing out and that frequent repairs are ahead, even when the appliance has many years of useful life remaining. Service contracts would tend to minimize the risk of keeping an appliance that seems failure-prone.

We could also take steps to ensure a continuation of parts supplies even for older appliances. The cost to manufacturers of carrying parts inventories for long periods is very large — between 20 and 30 per cent of the value of the inventory per year. Making a part or small batches of parts is also prohibitively expensive. A policy which permitted firms to write off older parts without destroying them would reduce this carrying cost significantly and

would enable the firm to recover part of the investment through reduction of income taxes.

And, finally, consumer information and education would enable consumers to make wise economic decisions in buying and using appliances. Making life-cycle cost information freely available in understandable, useful forms would give the public a basis for more conservative buying. Better instruction in operating and maintaining appliances is another public service that would tend to prolong appliance life.

While we advocate policies to lengthen product life, we do not recommend that development of recycling techniques should be diminished or halted, or that policy changes favoring recycling be abandoned. Products eventually will wear out, either in part or in whole, and will have to be discarded. At that point, the recovery of the residual material value becomes important. Recycling, when considered as a system that includes collection costs, still is a cost-absorbing system. Techniques and policies that put recycling on a better economic footing are necessary. We are suggesting here that extending product life is also important and that this area, too, can bring economic and environmental benefits.

Suggested Readings

Automobile Manufacturer Association, 1971 *Automobile Facts and Figures,* Detroit, 1971.

Baruch, Jordan, "Demanufacturing — Threat and Opportunity for Manufacturers," *Innovation,* No. 29, March, 1972.

Battelle Memorial Institute, "Final Report on a Survey and Analysis of the Supply and Availability of Obsolete Iron and Steel Scrap," January 15, 1957.

Conference Board The, *A Guide to Consumer Markets,* 1974/1975, Helen Axtel, ed., New York, N.Y., 1974.

Harwood, J. J., "Materials Resources — R & D Response," Paper presented at Industrial Research Institute Symposium, May 7, 1974.

Massachusetts Institute of Technology, Center for Policy Alternatives, *The Productivity of Servicing Consumer Durable Products,* Cambridge, Mass., June, 1974.

National Industrial Pollution Control Council, *The Disposal of Major Appliances,* U.S. Government Printing Office, Washington, D.C., June, 1971.

National Research Council Commission on Natural Resources, Committee on Mineral Resources and the Environment (COMRATE), *Report of Panel on Resource Recovery from Municipal Solid Wastes,* April 3-4, 1975, Publication pending.

Pennock, Jean L. and Carol M. Jaeger, "The Household Service Life and Durable Goods," *Journal of Home Economics,* January, 1964.

Randers, Jørgen, *The Dynamics of Solid Waste Generation,* Systems Dynamics Group, Alfred P. Sloan School of Management, Massachusetts Institute of Technology, June 1, 1971.

Ruffin, M. D., and K. S. Tippett, "Service-Life Expectancy of Household Appliances: New Estimates from the USDA," *Home Economics Research Journal,* March, 1975.

"1975 Statistical and Marketing Report," *Merchandising Week,* vol. 107, No. 8, Febraury 24, 1975.

Sullivan, P. M., Stanczyk, M. H., and Spendlove, M. J., *Resource Recovery from Raw Urban Refuse,* Report of Investigations 7760, U.S. Bureau of Mines, 1973.

U.S. Bureau of Labor Statistics, *Handbook of Labor Statistics,* Washington, D.C., U.S. Government Printing Office, Washington, D.C., 1974.

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A fascinating mix of intermediate technology vehicles has evolved to fit the transportation needs of Southeast Asians. Perhaps we can learn from their discoveries

An Indian tricycle driver has to contend, not only with a grueling job, but with extremes of weather from hot, dusty roads in the summer to flooded thoroughfares during the monsoon season. It might seem logical that Indian vehicles would have been adapted to such vagaries of climate and use, but logic is often far down the list of priorities for Indian transport, or for transport throughout Southeast Asia. In his travels, the author has uncovered some of the fascinating mechanisms behind Asian transport evolution. (Photo: Stock, Boston)

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Becaks, Bemos, Lambros and Productive Pandemonium

The streets of Southeast Asia are more than channels of transport. They are active centers of commerce and social interaction; the streets serve as residents' living rooms, kitchens, and sometimes bedrooms. Businesses use the streets as offices and warehouses. When water is scarce, the gutters may act as baths, laundries and sewers. Peddlers and tradesmen, offering an incredible variety of goods and services, fill the streets with their wares and calls for customers. Some are firmly established at profitable intersections; others move slowly along through the crowds.

Almost miraculously, traffic also flows through these streets. The most striking feature of this traffic is its variety — animals, pedestrians, and vehicles with two, three, or four wheels all jockey for passage through the choked thoroughfares. Closer examination reveals a method to the transportation madness, for each vehicle appears to serve a specific function in the transportation mix. Transportation engineers, or engineers in general, should not be surprised by this technological evolution to meet special requirements. However, the curious socially induced differences in the traffic mixtures between cities, even within the same country, are particularly intriguing.

The differences are not so much found in cars, buses or trucks — which are all of western design and scarcely change from country to country — but among the smaller, more primitive vehicles. It is upon the carts, bicycles, tricycles, motorcycles, motorized three-wheelers, and minibuses that the differing cultures exert their influence, constrained by economics and technology.

Transportation is perhaps even more vital in Southeast Asia than in the West. Telephones, postal services, and other communications facilities are notoriously unreliable, so the personal encounter is all-important to social and business interaction. Because personal trips are so frequent and necessary, the vehicles must be especially economic, using as few scarce resources as possible and depending primarily on the one resource plentiful in the area — human labor. It is especially surprising then, that the vehicles in South Asian cities have such a great variation in efficiencies. Even the most fundamental form of transportation of goods — carrying them on foot — varies from place to place. For instance, in Korea, goods are carried on the back using a wooden frame, but in Indochina, the load is divided into two parts, hung from the ends of a split bamboo pole, then balanced across the shoulder.

The bicycle is the most basic intermediate technology vehicle. In my travels over Southeast Asia I was amazed at the differences among countries in the speed and effectiveness of their bicycles. For example, once the Saigon government banned importation of motorcycles in the 1960s because of the economic crisis, bicycles with sturdy, simple frames began to evolve. Extra seats over the rear wheels allowed transportation of both people and freight. Small-wheeled bicycles with low frames were especially suitable for new or elderly riders. The Saigon bicycles were designed in sophisticated Saigon shop industries, which had turned from motorcycle maintenance and reconditioning. In fact, after the fall of South Vietnam, it was reported that Saigon bicycles spread rapidly north to Hanoi, where they contrasted sharply with the staid, simpler North Vietnamese bicycle.

The rapid adaptation of the effective Vietnamese bicycle was successful because of the economic need for it in the collapsing economy, and its ease of use by all kinds of people. The open structure of the society also encouraged bicycle use, because there were no social taboos against women or the elderly riding bicycles. Also, a traffic law designed to protect motorcyclists from automobiles benefited bicyclists. By this law, large yields to small, so when bicycles came on the scene they inherited a legal advantage over all the other vehicles.

The effective, rapid evolution of the bicycle in Saigon contrasts sharply with the virtual stagnation of design in India. The Indian bicycle in use today is identical to that used generations ago, which, in turn, was an imitation of the standard English model of the earlier era.

This slavish imitation is remarkable when one considers the sharp difference in the bicycle's function between the two countries. The English bicycle was designed to carry one person and move quickly on a paved road. Moreover, careful maintenance was expected. In contrast, an Indian bicycle must carry one, two, or possibly more persons, and sometimes a substantial amount of goods as well. Indian roads are often poor, and bicycle maintenance is minimal. In the summer, the roads get so hot that tire patches fail. The dust finds its way into every moving part, hastening deterioration. During the monsoon, bicycles are ridden on roads that resemble rivers. The greatest contrast between England and India, however, is in the attitudes of the riders toward their bicycling. In England the bicycle was a means of transportation much more rapid than walking; in India the object is to reach the destination quickly, but more importantly, to maintain a lower level of exertion. Thus, while Indian bicycle traffic seems to move more slowly, it is still a highly efficient mode of transportation for In-

dians, when considered in terms of conservation of energy, and the low value on time.

The Indian bicycle has not been redesigned to enhance its energy efficiency, ease of maintenance, or cargo-carrying ability, in large part because of India's strong social divisions. First of all, bicycle repairs are almost never done by the riders, but by repairmen of very low social status. These repairmen have established themselves along the major urban bicycle corridors, or simply under convenient shady trees. They own just enough tools to repair the most common malfunctions. Such a social taboo rules out any change in bicycle design which might enable the rider to repair his own vehicle. For instance, exchanging the currently used hex nut on the rear axle for a butterfly nut would enable the rider to tighten his own chain without tools (chain slackening is the most common malfunction on the Indian bicycle). However, such innovation is unlikely.

Similarly, bicycle designs with smaller wheels and a smaller frame will be slow to appear in India, for they would allow women in their saris to ride bicycles. Currently, most women are restricted to riding side-saddle as passengers on the luggage rack over the rear wheel. Innovations offered by organizations such as the Indian Institute of Design will almost certainly be stymied by conservatism and social prohibitions.

Of course, bicycles are by no means merely passenger carriers in the East. The luggage racks on Asian bicycles often carry up to 50 kilograms of goods strapped clumsily on the back. Jugs of milk, packages of food, and other perishables of high value are delivered rapidly by bicycles. Bakeries often use bicycles with large, wooden bread-boxes attached.

Three is Better Than Two

The most widely-used human-powered freight-carriers in Southeast Asia are the tricycles, perhaps the most fascinating form of intermediate transport. The pedal tricycle, alternatively known as the becak, cycle-rickshaw or pedicab, is always manufactured locally, and rarely exported outside the city of its manufacture. Tricycle "factories" are small shops, employing only a few persons. Families often pass the trade from generation to generation. Locally available materials and parts are used as much as possible; hence, standard bicycle frames and wood usually constitute the tricycle base. Welding is an important technology, but machine tools are rarely used. Considering the similarity of basic materials and the cost restraints throughout Southeast Asia, the wide variation

A tricycle driver takes a midday nap. Driving a tricycle is exhausting work, requiring at least an extra 1,000 calories a day. Most of the time a tricycle driver earns enough money — though never more than a few dollars per day — to buy enough food to maintain his high caloric requirements. (Photos: Alan K. Meier)

in both appearance and efficiency is surprising.

Tricyclists can carry up to 175 kilograms for level distances up to several kilometers. This capacity and distance depends greatly, of course, on the efficiency of design and the level of maintenance. The three fundamentally different tricycle designs place the driver either in front of the cargo or passengers, behind them, or the load on a side-car. In the driver-in-front tricycle, steering remains as on a regular bicycle, with power transmitted via a long chain to the two rear wheels. The driver-in-rear configuration features two front wheels, with power supplied to a single rear wheel. Steering is accomplished by turning the entire front compartment.

Each design has its own advantages and disadvantages. The driver-in-front design, used mostly in India, is lighter and easier to pedal and steer. However, side-car and driver-in-rear design, found in Indonesia, Malaysia, and Vietnam, can carry heavier loads, because power is transmitted more directly.

The importance of tricycles in the urban transport mix of Southeast Asian cities varies immensely. In the largest cities, they must compete with motor traffic and contend with an unsympathetic government administration which often discourages their use because they are "inhumane" or "a hazard to traffic." (Usually the government really means that the tricycles are a hazard to the autos belonging to the wealthy.) But government policies are not always effective in limiting the tricycles. In the city of Jakarta, Indonesia, about three times as many becaks run

An Indian bicycle repairman awaits a customer. He is probably wealthier than average, for it appears that he rents out the tricycle behind him. He is also well-located on a major thoroughfare, no doubt paying some sort of protection for the privilege.

As a city's economy progresses, motors replace muscles for powering vehicles. The citizens learn very quickly that they can push the load limits of their vehicles far beyond design specifications.

the streets as legal government licenses for them have been issued. The owners duplicate their licenses so as to run more than one vehicle. As a result of such large-city constraints, the tricycle is usually more important in the smaller cities.

Of all the tricycles, the Malaysian-type manufactured in Penang appears to be the most successful. These sturdy vehicles, some of which have lasted over 20 years, are used primarily to carry freight and serve as vehicles for food vendors. Stores own fleets of tricycles to make deliveries, and entire restaurants-on-wheels, complete with seating and kitchens, are operated from the front compartments of some vehicles. Freight-carrying will probably continue to be the forte of tricycles, for they can negotiate narrow city streets better than almost any motor vehicles, yet carry almost as much freight. The freight tricycle is still evolving, with gear ratios slowly dropping, and new, smaller wheels appearing (from motorcycles) to improve capacity and smooth the ride. Passenger tricycles, however, have all but disappeared due to competition from motor vehicles. One of the few remaining passenger functions of the tricycles is to transport small children to and from school.

Motors for Muscle

As a city's economy improves its technology advances, and motor transport almost invariably comes into wide use. The smallest motor vehicle in Southeast Asia is the "mo-ped" — a reinforced bicycle with a small gasoline engine attached. The engine is usually less than 50 cc. and usually produces less than two horsepower. The driver of a mo-ped can pedal, motor, or do both. Although a passenger or freight can be carried on the back, the motor must really strain, and often sputters to a halt if it is even a bit out of tune. The real center of current mo-ped activity is in India, where it is a vehicle of the upper classes. It is hoped that the mo-ped will soon be drafted to haul freight, pull two-wheeled carts, or be cannibalized to provide tricycle engines as they have been in Indochina.

With the addition of 20 cc. or so to its engine displacement, the mo-ped becomes a motorcycle, and can function as an excellent passenger and freight carrier. For example, in Vietnam, entire families of up to six people ride on a single 50 cc. motorcycle.

The technological evolution of a city to support motorcycles means not only a growth of repair facilities, etc., but also the improvement of roads. Potholes slow the motorcycles to bicycle speeds and shorten the life of the more expensive vehicle. In the Fiji Islands, the motorcycle's popularity skyrocketed when roads were paved. So quickly did the boom develop that some members of the motorcycle gang in Lautoka still rode motorcycles with a learner's "L" on their plates! Surprisingly, the wet weather of Southeast Asia plays a very minor role in motorcycle use, and the riders always seem to triumph over the weather. One unusual method motorcyclists use throughout Southeast Asia to protect themselves against rain is to wear their plastic raincoats backwards.

The Southeast Asians have developed the motorcycle into an effective intermediate-technology transport vehicle mainly by learning to "abuse" it to their advantage. They have discovered rather quickly that European and Japanese specifications for their motorcycles are very conservative, and in reality, the motorcycles can carry much greater loads than specified. Instead of two passengers, the motorcycles can carry three or four with additional seating in front of, or behind the driver. The motorcycle can also be adapted to carry an incredible variety of goods, including live pigs and chickens, bottled gas, sacks of rice, and bricks.

One of the most interesting adaptations of the motorcycles is not a change in technology, but of attitude — the idea that motorcycles can be used as taxis. In Saigon in the late 1960s motorcycle owners supplemented their income by transporting soldiers from barracks to night clubs. As the economy deteriorated in the 1970s, the incentive to profit from machines soared,

As a city's economy progresses, motors replace muscles for powering vehicles. The citizens learn very quickly that they can push the load limits of their vehicles far beyond design specifications

and although illegal, the "honda-ôms," as they were called, flourished. A bargain at half the price of a taxi, they were also safer at night than riding a motorcycle alone; so, even motorcycle owners left their vehicles at home to use them.

Three Wheels and a Motor

Just as the tricycle evolved logically from the bicycle, so the three-wheeled motor vehicle has come from the motorcycle. These are called variously helicaks, minicars, bemos, mebeas, auto-rickshaws, four-seaters, tempos, cycle-motors, lambros, and samlors. Each of these vehicles is distinctly different, due to the many, small local manufacturers, who vary the simple main design. The three wheels make them stable so they can be constructed more heavily. Thus, they are unlike motorcycles, where balance and weight reduction is vital. And they require far less sophisticated brakes, suspension, transmission and steering systems than regular automobiles, so the technology does not far outstrip local resources.

The range of technological sophistication in these vehicles is enormous. The crudest three-wheelers are simply reinforced tricycles, with an engine replacing the drivers' legs for locomotion. Because the tricycle frames cannot usually stand the strain of motor-power for long, the need for a stronger frame is immediately apparent, and the design proceeds to an even greater complexity. More sophisticated three-wheelers have been imported from Italy or Japan. These have engines of around 175 cc. and can carry from three to nine passengers. However, in many Asian countries, local industries have begun to produce a third generation of three-wheelers. Some countries, such as India, are merely importing the manufacturing technology, while others, such as Indonesia, have designed their own vehicles for local conditions. But most importantly, the influence over design is returning to the area of use, and is no longer merely an adaptation of semi-obsolete European and Japanese vehicles.

Undoubtedly the oddest three-wheeler is the helicak — a driver-in-rear motor vehicle with an egg-shaped, enclosed compartment resembling a helicopter cockpit. The helicak, with its tinted windows, is a high-status vehicle for its passengers, but there was concern at their introduction that the zippy vehicles would present quite a hazard to passengers in a collision. Despite cartoons, such as one showing a helicak with a mattress strapped to the front, there appeared, however, to be few serious accidents with the vehicles.

The three-wheeler is not equally popular in all countries. While huge numbers of the three-wheelers roam streets in India, the vehicles have already come and gone in Saigon and Bangkok, replaced by four-wheeled taxis and buses.

While the three-wheeler is widely used as a taxi, its real vocation is as a minibus. As three-wheelers came into use as minibuses, they grew larger, with about 500 to 700 kilograms of capacity. Seating arrangements changed from one seat facing forward into two benches facing each other, and the driver's compartment was separated from the passenger compartment. As with most transportation in Southeast Asia, fares were bargained over before the trip began. The price depended on the time of day, the amount of luggage, and whether competitive transportation was available. For example, if the local bus service was on strike, fares might double.

Most of the three-wheeled minibuses originated during the period of 1958 to 1965, and manufacturing ceased after that time. So, the minibuses now used in such places as Vietnam, Indonesia, and Thailand are being driven until they collapse. However, new three-wheel minibuses are approaching the production stage in both Indonesia and Greece. The minibus has proven economically and even politically important to Southeast Asia. For instance, the "lambro" minibus was used as a political weapon in Vietnam. The South Vietnamese government, in an attempt to give rural peasants a stake in the government, encouraged the drivers of these buses in the countryside to also become their owners. Presumably the Viet Cong would not tolerate this form of free enterprise, thought government officials, and the driver-entrepreneur would, thus, have an economic interest in keeping the South Vietnamese government in power. Eventually this idea spread to Saigon, where fleets of lambros operated on fixed routes in the city. However, in 1967, as thousands of motorcycles were imported into Vietnam, the minibus lost an important source of customers — middle-class commuters. The lambros held on until late 1974 when buses were introduced that offered more comfortable seating and a lower fare.

As I indicated previously, when technology and economics allowed, three-wheeled vehicles were replaced by four-wheeled vehicles. However, some reengineering was still performed on the basic four-wheelers to adapt foreign vehicles to Asian users. For instance, the Indonesian "opelets" were based on an Austin automobile chassis. The rear end of the body was removed and a station-wagon-type body made of wood was substituted. The opelet carried about nine passengers on two parallel

A school-bus tricycle in India, with at least eight children inside. Sometimes such buses feature a solid roof with a rack above for the children's lunch boxes.

bench seats in the rear. Besides the driver, there was invariably a boy manning the rear door, collecting fares, and calling out the opelet's destination to pedestrians.

Although such route-varying "jitneys" in Southeast Asia — as elsewhere — offered more flexibility and greater frequency than buses, the governments of Southeast Asia have discriminated against jitneys, because they are not as easily regulatable as buses. In Jakarta, for example, the opelets are limited to certain routes, thus depriving them of their flexibility. Fortunately, the jitneys are responding with improved, comfort-oriented technology to keep their market. For instance, small pickup trucks have been adapted as jitneys to give better rides. These have proven so successful that within three years of their introduction in Bandung, Indonesia, they had virtually displaced the opelets. Although such rapid transformations of transportation technology are quite common in Southeast Asia, a similar quick turnabout in the huge, capital-intensive transportation systems in U.S. cities is unimaginable.

Many of the transportation forms discussed here have arisen spontaneously in response to social needs, but the hand of the government has also been felt in Southeast Asian transport, both for good and bad. Motorcycles were deliberately introduced into Vietnam, on the advice of American economic advisors, to sop up excess dollars being earned by the Vietnamese workers. The Indian government sponsored the tricycle to replace hand-pulled rickshaws, because the former were more "humane." The officially approved driver-in-front design, however, was

Clockwise from upper left: A Penang bakery's delivery tricycle speeds the fresh bread from merchant to consumer; a lambro carrying freight and a passenger in Saigon; a helicak of Jakarta: the egg-shaped passenger compartment is quite strong, the tinted windows offer protection from the heat and it is considered a high-status means of transport; the super helicak of Jakarta is one of the forerunners of sophisticated domestically produced vehicles.

the only tricycle encouraged, using such policies as low-interest bank loans. Similarly the Indian government has limited motorized three-wheeler design by allowing importation of only a few designs.

Sometimes government transportation policy has little to do with technology or "humaneness." There is a story, perhaps apocryphal, that the Japanese bemo three-wheeler was introduced into Indonesia because the Japanese were so delighted when Sukarno married his Japanese mistress that they gave him a special deal on them. Questionable bargains of some type often play a role in transportation and other government decisions in Southeast Asia, but they are obviously difficult to trace.

This incomplete description of intermediate transport in Southeast Asia illustrates the diversity of solutions available to answer the problem of moving people and freight around a city with a minimum of resources. The intermediate technology transport sector is ideally suited to these societies, because the marginal cost of additional transportation capacity is small for the entrepeneur and, for the government, often nothing. Usually the organization required to sustain the network arises spontaneously and is efficient, at least until it achieves a monopoly. Therefore, the one transportation policy really essential to Southeast Asia is that competitive modes of transport should be encouraged. These modes would provide slightly differentiated transport packages. For instance one mode might be like another, except the second can carry freight; one mode might be slightly more expensive than another, but faster. Thus, each mode would have a definite market, but would be able to assume a competitor's responsibility in the event of a strike or similar disturbance.

The key to effective urban transport in Southeast Asia is flexibility. Rapid change has been seen to occur in a transport system, even in peacetime. The last thing a rapidly growing city should do is make long-term commitments to urban transport, such as fixed rail systems. The city may be completely transformed before the plans leave the drawing board. Any government commitment should be to insure that the poor have a means of transport, as well as a livelihood in the transport industry (even if it means driving an "inhumane" tricycle).

Southeast Asian vehicle use will certainly grow, although the direction depends upon a myriad of social, political, and economic factors. In a situation where private entrepreneurs are encouraged, there will be a move toward small motorized vehicles and, later, buses. At almost every level of passenger transport, motor vehicles are more efficient. One motorized three-wheeler can substitute for (or displace) 15 to 40 passenger tricycles. The individual entrepreneur can realize a better return on the motorized three-wheeler than on a fleet of tricycles. On a national scale, however, the shift to motorized transport is a disaster. Unemployment in Indonesia is estimated to be over 25 per cent. Can the government tolerate a shift to motor vehicles when each new three-wheeler deprives 15 to 40 persons of jobs? Thus, there is an inherent contradiction of national and private interests. On the other hand, motorized transport may transform the society into an even more productive entity, stimulating a need for labor greater than any displaced. This appears to be happening in many small villages in Greece. There, the introduction of a sturdy, motorized three-wheel farm vehicle has reestablished the farm as a viable, economic unit. Still, there is no guarantee that the motorization of transportation will be successful enough to reconcile the conflict of private and national interests.

Such intermediate-technology vehicles may soon blossom in the developed countries as a variety of factors leads to the future de-emphasis of private automobiles. Besides environmental and economic restraints on autos, there have arisen auto-free areas, in the form of pedestrian malls and residence complexes, which may also encourage the friendly, neighborhood minibus. As such areas increase in size, more sophisticated transport service, for both passengers and freight, will be required. Here, too, smaller vehicles — bicycles, motorcycles, and three-wheelers — could provide efficient unimposing service that does not disrupt pedestrian activity.

Alan K. Meier is a man of many parts. After receiving B.A.'s in both chemistry and economics from the University of California at Berkeley in 1974, he spent a semester in Munich, Germany, studying organic chemistry, and a year at the University of Pennsylvania studying biological chemistry. He is currently working toward his Ph.D. at Berkeley, studying energy conservation measures in the home.

He has recently turned his interest in technological innovation and its affects on social structures toward the United States, where he plans to continue his studies of intermediate transport. He predicts that there is a mo-ped in our future.

A more complete account, entitled "Intermediate Urban Transport in Southeast Asia," will be published as an informal Brookhaven Report by the Biomedical and Environmental Assessment Division of Brookhaven National Laboratory, Upton, L.I., N.Y. 11973.

How to Celebrate Election Day and a New Year, Too

Puzzle Corner
by
Allan J. Gottlieb

How fitting to be writing a puzzle column on Election Day 1976 — a real puzzle!

Last month I had a pleasant surprise. One of my wife's colleagues, Scott Brodie, came to tell us that Martin Gardner had again mentioned "Puzzle Corner" in his highly respected column in *Scientific American*. I should like to thank him for the generous comment.

A final remark before getting down to serious business: the backlog of "speed" problems is still low.

Problems

Y1977 Since this is the January issue, we once again present a "yearly" problem — this time Y1977. You are to take the digits 1, 9, 7, and 7; and the operators +, −, * (multiply), / (divide), and ** (exponentiation); and form the integers from 1 to 100 using each digit once (7 is thus used twice) and the fewest possible number of operators. Parentheses may be used to indicate the order of operations and, in case of a tie in the number of operators, a solution using 1 9 7 7 in order is to be favored.

The answers to Y1976 appear under "Solutions" below. The deadline for Y1977 is November 1 so that we may report the solutions next January.

JAN 1 We begin with a five-card bridge problem from Emmet J. Duffy: With a no-trump contract, how can South, who is on lead, make a remaining five tricks against any defense?

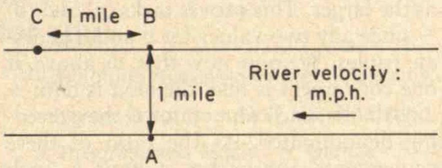
	North	
	♠ 8 ♥ Q 7 ♦ 9 ♣ 10	
♠ A ♥ 10 9 6 ♦ 8 ♣ –		♠ – ♥ – ♦ A 7 ♣ Q 9 6
	♠ – ♥ J ♦ J 5 ♣ A 8	

JAN 2 To accord with our political theme, I offer the following criptarithmetic puzzle from Rank Rubin: Replace each letter by a unique decimal digit to make a correct equation:

$$\begin{array}{r} \text{ROBERT} \\ \times \quad \text{F} \\ \hline \text{KENNEDY} \end{array}$$

JAN 3 A number-theory problem from R. E. Crandall: Prove that if X, . . ., Xn are distinct real numbers (distinct natural numbers are all right, too) and n > 1, then the finite sequence $\{Xi\}^{n}_{i=1}$ has a monotone subsequence of length greater than $\sqrt{n}$.

JAN 4 An athletic problem from Ted Mita: A swimmer, who swims at a constant rate of two miles per hour relative to the water, wants to swim directly from point A to a point C, which is one mile downstream and on the other side of a river one mile wide and flowing one mile per hour. At what angle should he point himself, relative to the line AB (perpendicular to the river)?



(Getting the equation right is a sufficient solution, since one needs tables to obtain the final answer.)

JAN 5 To again honor the elections, we close with a problem based on international monetary exchange submitted by Homer D. Schaaf: An ounce of gold can be drawn into 50 miles of wire or hammered into a sheet of 100 square feet. Which is thicker, the wire or the sheet? Hint: Gold, unlike currencies, does not float.

Speed Department

JAN SD1 People say Jimmy Carter is very calculating. Speaking of calculators, Don Savage submits the following: One consequence of the recent purchase of my first calculator was loss of sleep from staying up to the wee hours merrily pushing buttons. So here is a three-part quickie for my fellow calculator freaks:

I. $\dfrac{1}{9 \times 9} = ?, \dfrac{1}{9 \times 99} = ?, \dfrac{1}{9 \times 999} = ?,$

$\dfrac{1}{99 \times 99} = ?, \dfrac{1}{999 \times 999} = ?, \dfrac{1}{9999 \times 9999} = ?$

II. $\sqrt[\pi]{e} \overset{?}{=} \sqrt[\pi]{\dfrac{100}{11}}$

III. $\dfrac{104348}{33215} = ?$

JAN SD2 Norman Spencer has the spirit: On the first day of Christmas my true love gave to me a partridge in a pear tree. On the twelfth day she gave me 78 gifts. How many gifts did I receive altogether?

Solutions

Y1976 Take the digits 1, 9, 7, and 6; the operators +, −, * (multiply), / (divide), and ** (exponentiate); and form the integers from 1 to 100 using each digit once and the lowest possible number of operators. Use parentheses to indicate the order of operation, and in case of a tie a solution using 1 9 7 6 in order is favored.

Several people arrived at the following solution:

Number	*Score*	
1	1*	1^{976}
2	1	71 − 69
3	3*	1/[(9-7)/6]
4	1	76/19
5	2	$6 - 1^{97}$
6	2*	$(1^{97}) \cdot 6$
7	2*	$(1^{97}) + 6$
8	2	$(1^{96}) + 7$
9	2	$(1^{76}) \cdot 9$
10	2	$(1^{76}) + 9$
11	3*	[(1 + 9) + 7] − 6
12	2	96/(1 + 7)
13	2	(79 − 1)/6
14	2	(17 − 9) + 6
15	1	91 − 76
16	2	(97 − 1)/6
17	2	71 − (9 · 6)
18	1	79 − 61
19	2*	19 · (7 − 6)
20	2*	(19 + 7) − 6
21	3	[(1 · 9) − 6] · 7
22	3*	[(1 · 9) + 7] + 6
23	2	(7 · 6) − 19
24	1	91 − 67
25	1	96 − 71
26	3	[7 · (6 − 1)] − 9
27	3	[(7 − 1) · 6] − 9
28	1	196/7
29		No solution
30		No solution
31		No solution
32	2*	(19 + 7) + 6
33	3	[(1 · 7) · 6] − 9
34	3*	(1 − 9) + (7 · 6)
35	3	$7 \cdot (6 - 1^{9})$
36	1	97 − 61
37	2	(9 · 6) − 17
38	3	[9 · (6 − 1)] − 7
39	3	[(1 + 7) · 6] − 9

40	3	$[(1+6)\cdot 7]-9$
41	3	$[(9-1)\cdot 6]-7$
42	3*	$1^9\cdot 7\cdot 6$
43	3	$(7\cdot 6)+1^9$
44	3	$9-[(1-6)\cdot 7]$
45	2	$(61-9)-7$
46	3	$[(9\cdot 6)-1]-7$
47	2	$(9\cdot 7)-16$
48	1	$67-19$
49	2	$(16-9)\cdot 7$
50	3	$[(9-1)\cdot 7]-6$
51	2	$17\cdot(9-6)$
52	1	$69-17$
53	3	$[(1+9)\cdot 6]-7$
54	3	$(1^7\cdot 9)\cdot 6$
55	3	$[(9-1).6]+7$
56	2	$(71-9)-6$
57	1	$76-19$
58	2	$(1.67)-9$
59	2	$(1-9)+67$
60	3	$(1^7+9)\cdot 6$
61	2*	$19+(7\cdot 6)$
62	2	$(1\cdot 69)-7$
63	1	$79-16$
64	3*	$[(1+9)\cdot 7]-6$
65	3*	$1+(9-7)^6$
66	2	$(76-1)-9$
67	2	$1^9\cdot 67$
68	2*	$(1-9)+76$
69	2	$1^7\cdot 69$
70	2	1^7+69
71	2	$17+(9\cdot 6)$
72	2*	$(19-7)\cdot 6$
73	2	$(1\cdot 79)-6$
74	2	$(1+79)-6$
75	2	$(9-1)+67$
76	2*	$1^9\cdot 76$
77	2*	1^9+76
78	2	$(91-7)-6$
79	1	$96-17$
80	2	1^6+79
81	1	$97-16$
82		No solution
83		No solution
84	2	$(9-1)+76$
85	2*	$(1\cdot 9)+76$
86	1	$19+67$
87		No solution
88	2	$(96-1)-7$
89	2	$(1\cdot 96)-7$
90	2	$(1+96)-7$
91	2*	$(1\cdot 97)-6$
92	2*	$(1+97)-6$
93	2	$(17\cdot 6)-9$
94		No solution
95	1*	$19+76$
96	2	$1^7\cdot 96$
97	2	1^7+96
98	2	1^6+97
99	2	$(17-6)\cdot 9$
100		No solution

Asterisks mark the favored solutions in which 1 9 7 6 appear in order.

Responses were received from Gerald Blum, Albert S. Knight, W. Robert Dresser, Abraham Schwartz, Glenn Rowsam, A. W. Collins, Avi Ornstein, E. Jamin, Robert K. Kennedy, Harry Zaremba, Richard Rudell, R. Bart, A. Holt, Edward Pierce, and William J. Butler, Jr.

J/A 1 Since a clarification was given in the last issue, the solutions will appear in March/April.

J/A 2 It is well known that Pythagorean triples with integers a, b, h, where $a^2 + b^2 = h^2$, may be generated by taking $h = p^2 + q^2$, $a = p^2 - q^2$, and $b = 2\,pq$, where p and q are any integers such that $p > q \geq 1$. A special series of such triples is that in which the legs a and b differ by one unit. By means of a table of squares we can find that the first four of such triples are:

p	q	h	a	b
2	1	5	3	4
5	2	29	21	20
12	5	169	119	120
29	12	985	697	696

(For the tenth such triple, p = 5741, q = 2378, h = 38,613,965, a = 27,304,197, and b = 27,304,196.) If we take the fractions q/p from the table above, they are 1/2, 2/5, 5/12, and 12/29. These are the continued fraction approximants for $\sqrt{2} - 1$. Prove that all the approximants (a) result in Pythagorean triples (b) with legs differing by unity, and (c) that the dimensions increase nearly geometrically with a ratio approaching $(3 + 2\sqrt{2})$.

I received several accurate responses to this problem, and I selected R. Robinson Rowe's due to its clarity and simplicity:

As a continued fraction,

$$\sqrt{2} - 1 = \cfrac{1}{2 + \cfrac{1}{2 + \cfrac{1}{2 + \cfrac{1}{2 + \cdots}}}}$$

indefinitely, and if at any stage the part in the oval is the preceding convergent m/n, this succeeding convergent is

$$C = \frac{1}{2 + m/n} = \frac{n}{m + 2n}$$

If that preceding convergent generated a triple $a^2 + b^2 = h^2$ with $a - b = \pm 1$ by the parameters $m = q$, $n = p$, $a = p^2 - q^2$, $b = 2pq$, $h = p^2 + q^2$, we have

$$p^2 - q^2 - 2pq = \pm 1 = n^2 - m^2 - 2mn$$

Then in the succeeding convergent,

$$\begin{aligned} q &= n, \\ p &= m + 2n, \\ a &= (m + 2n)^2 - n^2 = 3n^2 + 4mn + m^2 \\ b &= 2n(m + 2n) \qquad = 4n^2 + 2mn \\ a - b &= -n^2 + m^2 + 2mn = -(\pm 1) \end{aligned}$$

That is, the triple generated by the succeeding convergent will also have legs differing by unity, but a and b will alternate as the larger. This proves tasks (a) and (b) — since any two values for p and q generate triples. We note now that, as above, if one convergent is m/n, the next is n/(m + 2n), that is, each numerator is the preceding denominator. As the ratio of these convergents approaches a limit r, such that n = mr, we have for consecutive convergents

$$\frac{m}{mr} \text{ and } \frac{mr}{mr^2}$$

and by the equation above for C,

$$\begin{aligned} mr^2 &= m + 2mr \\ r^2 - 2r - 1 &= 0 \\ r &= 1 + \sqrt{2}. \end{aligned}$$

Then, from b = 2pq, consecutive b's and $2m^2r$ and $2m^2r^3$ with a ratio of

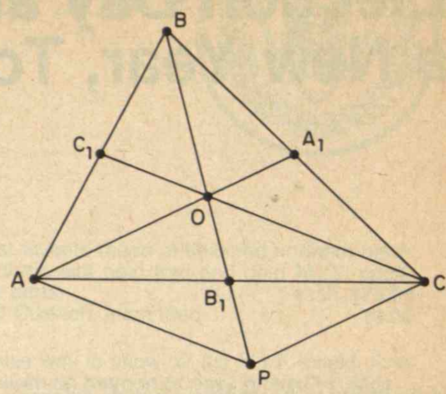
$$r^2 = (1 + \sqrt{2})^2 = 3 + 2\sqrt{2}. \qquad \text{qed}$$

Also solved by Charles J. Rife, John Bonomo, Winslow H Hartford, Gerald Blum, John F. Chandler, and the proposer, Irving L. Hopkins

J/A3 Construct a triangle given the lengths of the three meridians.

Harry Zaremba had little trouble with this one:

Let the given means be M_A, M_B, and M_C, each of which is trisected, initially. Armed with the foreknowledge that the intersection of the means is a point of their trisection and is the centroid of the triangle to be constructed, we proceed as follows (see figure):



(1) Draw line BB, whose length equals M_B.
(2) With B_1 as the center and $M_B/3$ as the radius, locate points O and P on line BB_1.
(3) With points O and P as centers, and $2M_A/3$ and $2M_C/3$ as the radii, respectively, locate point A.
(4) Similarly, using O and P as centers, and $2M_c/3$ and $2M_A/3$ as the respective radii, locate point C.
(5) Draw the figure AOCP, and line AC. Since AP = OC, and AO = PC, the quadrangle is a parallelogram. Diagonals AC and OP bisect each other at point B_1, and line AC is one side of the required triangle.
(6) Draw lines AB and BC. The figure ABC is the triangle required. Lines AA_1 and CC_1, extensions of AO and CO, respectively, are equal to the means M_A and M_C.

Also solved by John F. Chandler, R. Robinson Rowe, William J. Butler, Jr., Mary Lindenberg, Ernest W. Thiele, and the proposer, Robert Pogoff.

J/A4 Write down in a row the coefficients of the expansion of $(a + b)^N$ where N is any integer. Multiply each coefficient by the second coefficient and set the result below the multiplied coefficient. Continue by multiplying by the third, fourth, and fifth coefficients, etc. An example is shown for the coefficients of the expansion of $(a + b)^4$:

1	4	6	4	1
4	16	24	16	4
6	24	36	24	6
4	16	24	16	4
1	4	6	4	1

Find a formula for the sum of the digits in any diagonal.

Neil Cohen's clever method utilizing expansions of $(a + b)^S$ makes this look almost trivial:

Let A_{ij}^N be the coefficient in the ith row and jth column of the array created by the coefficients of the expansion $(a + b)^N$. Then $A_{ij}^N = C(N, i - 1)\,C(N, j - 1)$. By symmetry, it is sufficient to consider diagonals beginning with a coefficient on row 1 and slanting to the left. Pick the


LOVE
at first
BYTE

coefficient in the kth column. Then S, the sum =

$$\sum_{l=0}^{k-1} A^N_{(l+1,k-l)} = \sum_{p=0}^{k-1} C(N,l)C(N,k-l-1).$$

However, $(a + b)^{2N} = (a + b)^N (a + b)^N$. Therefore, $c(2N,k) =$

$$\sum_{l=0}^{k} C(N,l)C(n,k-l)$$

since the lefthand side is the coefficient of $a^k b^{(2N-k)}$ in the expansion of $(a + b)^{2N}$ and the right hand side is the coefficient of $a^k b^{(2N-k)}$ obtained by expanding $(a + b)^N$ and multiplying the resulting polynomial by itself. Therfore, $S = C(2N, k - 1)$.

Also solved by John F. Chandler, Willaim J. Butler, Jr., R. Robinson Rowe, Harry Zaremba, Gerald Blum, Winslow H. Hartford, William G. Hutchinson, Jr., Frank Carbin, Joseph G. Haubrich, Naomi Markovitz, and the proposer, Emmet J. Duffy.

J/A5 Given a decanter of wine but no measuring devices, find a way to divide the wine among any number of people so that each is satisfied that his/her share is (at least) a fair one. Assume that each person is willing to divide the wine and accept any of the portions.

An excellent response was received from Hal R. Varian, who says there are at least two solutions:

(1) One person pours the wine until someone yells "stop." The person who yells gets the serving. (Of course the pourer can also yell "stop.")

(2) Person one pours a glass of wine and passes it to person two. Person two can either pass it on untouched or pour some back into the decanter. So it goes on down the line. When the last person has had his chance to do this, the glass is awarded to the person who poured last. (Of course this could be the person who originally poured the glass.) The person who gets the glass is out and the process is repeated until only two people are left; then one divides and the other chooses. Mr. Varian notes that "several eminent mathematicians have worked on this problem, among them Banach and Steinhaus. Some of their work is described in Spanier and Dubins' 'How to Cut a Cake Fairly,' *American Mathematical Monthly*, Vol. 68, 1961, and Kuhn, H., 'Games of Fair Division,' in Shubik, ed. *Essays in Mathematical Economics*, Princeton University Press, 1967. I became interested in this subject while in graduate school at Berkeley and ended up writing my thesis on some formal models of distributive justice. A student of mine at M.I.T., Vincent Crawford, considered a variation of this problem in his 1976 Ph.D. thesis. Suppose that the item to be divided is nonhomogeneous — for example, a cake with icing. The two people involved in the division process may have different tastes for icing and cake, so they will evaluate different slices differently. It is not hard to show that divide and choose still has the "no envy" property — neither person will prefer the other person's piece to his own. The question Crawford asked is: In such a game is it better to be the divider or the chooser? Assume that each person knows the other person's tastes completely."

Also solved by Neil Cohen, Joseph G. Haubrich, R. Robinson Rowe, William J. Butler, Jr., Stephen Polloch, Jacob Bergmann, Neil E. Hopkins, Harris Hyman, and the proposer, Stuart Schulman.

Better Late Than Never

1975 DEC 2 Winthrop M. Leeds has responded with the following problem:

In the July/August issue you reported that David R. Kramer has solutions for K = 5 and K = 13 and asked for a procedure for all K. For large values of K where a strictly analytical solution does not seem practical, I suggest using the following procedure:

Draw a large circle, centrally located in the unit square, which intersects the sides of the square at a distance "x" from a corner where "x" is about 0.25 or 0.30. Completely cover one exposed corner of the square with N small circles with the pattern chosen for a minimum amount of overlap with each other and the edges of the corner space. Since all corners are assumed to be covered in the same way, then $K = 4N + 1$. Now measure the radius of each small circle and express it as a decimal fraction of "x," or kx. The radius of the large circle is $r = \sqrt{(.5)^2 + (.5 - x)^2}$. Now the sum of the areas of all K circles (call it A) can be expressed as a function of "x." Then calculate dA/dx, equate it to zero and solve for "x." If this is not too much different from the originally estimated value, then the value of A for this value of "x" will be very close to the minimum value of the total circle area for the chosen pattern. Here are some of my answers:

K = 13	A = 1.188
K = 21	A = 1.146
K = 37	A = 1.133
K = 45	A = 1.123

What would you think of asking your readers to find the smallest value for K that will yield a minimum for A = 1.100 or less?

[Any takers? — Ed.] You have asked what the procedure should be for infinitely large values of K where A should approach 1. I suggest that you start with an inscribed circle of radius 1, then put a tangential circle in each corner, continue with tangential circles in each uncovered crevice, and as the crevices and added circles get smaller and smaller:

$$\begin{cases} K \to \infty \\ A \to 1. \end{cases}$$

FEB 4 Bruce Andeen "strongly disagrees" with the solution published in October/November:

The error is in assuming that the displacement of the ship has any bearing on the water required to operate a lock. The amount of water that must be supplied to (or drained from) a lock to raise (or lower) a given ship is solely equivalent to the volume of the lock. The ship's displacement has already been accounted for, since when the ship entered the lock, the water in the lock is in equilibrium with the body of water from which the ship sailed. Only changes in the ship's displacement occuring *during* the lock operation affect the water requirement. Thus, the correct answer to the problem is *not* $2V_L - V_s$, as stated, but rather $2V_L$.

M/A Mazie Porter has responded.

MAY 3 Lowell Kolb has responded.

J/A SD 1 Neil Hopkins points out the interesting possibility:

$$2^2 + (3/2)^2 = (5/2)^2;$$

A, B, and C are all "limited to primes."

O/N SD 1 Several readers point out that the position could not occur in a game (even after you put the White King somewhere). What could the position have been before White mated? The only defense is that the position was not required to be "game born". While game born positions do exist they A: require the White King, and B: are not nearly so pretty.

Solutions to Speed Department

SD1 I won't ruin your fun by spilling the beans. Buy a calculator and find out for yourself, or "test one out" at Sears.

SD 2 $1 + (1 + 2) + (1 + 2 + 3) + \ldots + (1 + \ldots + 12) = 364$

The proposor claims that finite difference techniques yield a general solution

$$\frac{n \cdot (n^2 + 3n + 2)}{6}$$

But that sort of stuff is forbidden in the Speed Department.

Allan J. Gottlieb studied mathematics at M.I.T. (S.B. 1967) and Brandeis (A.M. 1968, Ph.D. 1973); he is now Coordinator of Computer Activities at York College of C.U.N.Y. Send problems, solutions, and comments to him at the Department of Mathematics, York College, Jamaica, N.Y. 11451.

An Institute Informant

The Editors' digest of recent and current concerns at the Massachusetts Institute of Technology

Who Cares About Space?

Remember Dick Tracy's wristwatch-radio-communications system?

Not so far-fetched after all, says Russell L. (Rusty) Schweickart, the lunar module pilot on Apollo IX who is now Assistant for Payload Operations in N.A.S.A.'s Space Shuttle Program. A high-power orbiting transponder is on the Shuttle's agenda, said Mr. Schweickart at an M.I.T. seminar last fall (he graduated from the Institute in the Class of 1956), and it could bring life to Dick Tracy's miniature miracle.

Mr. Schweickart's purpose was to urge for his student audience the practical importance of space — and to give these would-be engineers a warning. Two examples among many of the pay-offs from space research: communications satellites — they've halved the cost of a trans-Atlantic phone conversation and brought television to Indian peasants — and Landsat surveys of earth resources, helping study land use in the Sahel, for example, and fight mosquitoes in Louisiana.

But it's a frustrating business, because most of the pay-offs from space are not so dramatic as a Dick Tracy wristwatch, and people don't really care. The technology that "pays for the romance and the space colonies . . . is boring as hell . . . Everyone wants to know that his tax dollar is doing good, but no one wants to hear the specifics . . . People are satisfied with assurances, and then they want to talk about life on Mars."

"Selling" space technology is now part of Russell L. Schweickart's job — a tough job because people know that "start-up costs are tremendous" and the risks high but they don't realize that "on-the-ground user costs turn out to be very low." Communications by satellite and Landsat earth resources surveys are two examples, he said, and there will be many more from the Space Shuttle, for which Mr. Schweickart is now Assistant for Payload Operations. (Photo: John Bradstreet for *The Tech)*

Symposium on X-Ray Astronomy

Since SAS-3 was launched in May, 1975 (it's been operating flawlessly ever since) this orbiting x-ray observatory designed and monitored by the M.I.T. Center for Space Research has located the first "high-temperature white dwarf" star, the first "rapid-burster" x-ray source, and countless less exotic new x-ray radiators in the heavens.

These findings as well as experiments planned for the future will be reviewed at a day-long symposium in Cambridge on January 26; speakers will include Professors Hale V. Bradt, George W. Clark, Walter H. G. Lewin, Saul A. Rappaport, and Dr. Herbert W. Schnopper. There will be an introductory paper on the history of x-ray astronomy by Bruno B. Rossi, Institute Professor, Emeritus, and a conclusion on current and future implications of space research by Philip Morrison, Professor of Physics.

For further information, write Professor Claude R. Canizares, Room 37-501, M.I.T., Cambridge, Mass., 02139 — (617) 253-7500.

A Nuclear Advocate on Solar Power

It was a conference to promote New England solar energy development. But Richard S. Morse, President of the M.I.T. Development Foundation, Inc., turned on the cold water.

"No *significant* amount of energy, either thermal or electric, will be generated from the sun in this area in the next few decades," he told delegates to the New England Council's meeting late last fall. Adequate technology is still far distant, and there are two institutional constraints, as well:

— Among its responsibilities, the Energy Research and Development Administration is directed to commercialize the products of its laboratories. That's a new role for a federal agency, said Mr. Morse, and success is not assured and surely will not be instantaneous.

— Because the building industry "has never been noted for an ability to respond to changing technology," Mr. Morse suggests that "new mechanisms for forcing innovation" may well be needed.

Instead of the sun, let New England focus on nuclear energy in the near-term. It represents a special opportunity, unique in New England's recent history: power can be made with fuel that is no more expensive here then anywhere else in the U.S.

Next: The 1985 Census

Who will live and work where in 1985?

A new resource for planners who need to answer that question for their own region or city is now becoming available from the Joint Center for Urban Studies of M.I.T. and Harvard.

Two years ago David L. Birch, Senior Research Scientist at the Joint Center, divided the U.S. into 315 small areas mostly consistent with metropolitan and rural parts of the Bureau of Economic Analysis areas. Since then he's assembled data on the inflow and outflow of people and business in each of these areas between 1930 and 1975, including personal data on households that moved and descriptive and financial data on businesses.

Now a simulation model has been completed on the basis of this data, and from it can come detailed population and employment forecasts on a year-by-year basis through 1985 for each of the 315 areas. Both data and model results can be accessed by telephone terminals. The Joint Center welcomes inquiries — (617) 868-1410.

Hindsight on Foresight: Assessing the Telephone

What did Alexander Graham Bell and the others who helped develop his telephonic invention think might be its impact?

In a sense they were bullish from the beginning. Less than two years after his invention, Mr. Bell was talking about how "a man in one part of the country may communicate by word of mouth with another in a distant place." And some of his colleagues soon proposed that if a voice could travel over wire, pictures could be transmitted as well.

But was this really technology assessment? Kay F. Israel, an M.I.T. graduate student who's been engaged for two years in a "retrospective technology assessment" of the telephone under National Science Foundation sponsorship, thinks not. Despite their awareness of some of its potential, the pioneers of the telephone really had no idea of how its future miracles would be accomplished.

Professor Ted R. I. Greenwood of the Department of Political Science also maintains a posture of skepticism. The telephone pioneers' prognostications were made at a time when "telephone wires could only carry one message instead of 60,000," he says, and he finds himself among "the people who think that planning is less than it's cracked up to be."

The idea of the "retrospective technology assessment" of the telephone was to learn from the past about how technology assessment might work in the future. A full report of the two-year project is due later this year.

Salisbury

Continued from p. 7

stronger color forces.

In fact, if this force is as strong as a number of theoreticians now suggest, it may never be possible to produce a single quark. Electromagnetic and gravitational forces both are three-dimensional and decrease rapidly as the distance between two objects increases. But color force may be one-dimensional, like a string, and remain constant regardless of distance.

To separate two of these infinitesimal particles by an inch would require as much energy as it takes to raise a person 30 ft. in the air, says Dr. Glashow. And before the particles could be separated, another process would intervene. A quark-antiquark pair would materialize and one of these new particles would combine with the quark which was being separated to form a new hadron.

Thus quarks may be permanently inaccessible and invisible, and millenia of human speculation about the matter of the universe may have reached an ambiguous conclusion. As Dr. Nambu has written, "The very successes of the quark model lead us back to the question of the reality of quarks. If a particle cannot be isolated or observed, even in theory, how will we ever be able to know that it exists?

David Salisbury is Science Editor for the Christian Science Monitor *and writes regularly for* Technology Review.

Classified

Boulding

Continued from p. 8

trouble. The evil that people do in the name of doing good, the vast misperceptions of what constitutes betterment, and the excruciating difficulties of political choice, all cry out for treatment.

If someone objects that normative science is simply philosophy, I would not mind very much, for philosophy is much too important to be left only to philosophers. But I hope that normative science would be something a little more and a little less than philosophy. A little more because it could marshall the empirical facts needed to guide the formation of values, and less because it would not pretend to answer or even perhaps to ask the great questions about ultimate values and the nature and meaning of the universe which we must go on asking even if there are no answers.

In a sense, normative science already exists. The policy sciences, as Harold Lasswell called them, are indeed the foundation. The peace research movement is an example of the effort to develop a normative science in a specialized field. Marxism is an early example of a normative science which to my mind went wrong and probably did more harm than good. But Marxism points dramatically to the need for normative evaluations of ideological systems in the hope of inhibiting spurious yet persuasive beliefs in the future.

There is always the danger that normative science itself, especially if it has too much initial success, could become a constricting and damaging ideology. A principle of normative science already well established is that goods and evils are always produced jointly, and that for anything good we must accept at least the possibility of something evil. But we can work on that syndrome, as well, to increase the chance of good and diminish the chance of bad. If normative science can become a genuine discipline, its chances for benefit should increase and its dangers diminish. Normative science might even be capable of evaluating itself.

Kenneth E. Boulding is Director of the Institute of Behavioral Science at the University of Colorado. He writes regularly for Technology Review.